Energy audit at Mark Auto Industries Ltd

Prepared for Mark Auto Industries Ltd, Gurgaon

TERI Project Report No. 2002IE66

Final
Feb. 2003

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A suggested format for citing this report is as follows.

TERI. 2003
Energy Audit at Mark Auto Industries Ltd
New Delhi: Tata Energy Research Institute. 114 pp.
[TERI Project Report No. 2002IE66]

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Contents

Acknowledgement

Executive Summary

Chapters

1. Thermic Fluid Heaters (Thermopacs) 1

2. Ovens 7

3. Pumps 13

4. Electrical Systems 19

5. Electric Motors 29

6. Compressed Air Systems 33

7. Cooling Towers 41

8. Solar Thermal Energy 45

Annexures

Acknowledgement

Tata Energy Research Institute (TERI) places on record its sincere thanks to Mark Auto Industries Ltd, Gurgaon for entrusting TERI with the assignment of energy audit of their plant at Gurgaon.

We also wish to thank Mr Kallol Roy/Managing Director, Mr S K Arya/ Divisional Manager (Main. & Projects Engg), Mr B R Gola/Asstt Manager (Maint.), and Mr Manoj Kaushik/Sr Engineer – Main. Elec. and their staff for helping the energy audit team and providing them with the necessary support during the study.

Executive summary

Thermic fluid heaters (Thermopac)

Efficiency of the Thermopac#1 and #2 are calculated to be 74.75% and 80.35%, respectively. Heat duty of these is 62% and 64% of the design capacity, respectively. It is suggested to utilise the available capacity of thermopacks to replace the electrical heating in electrical oven.

Excess air levels were measured to be 96% and 79% in flue gases of thermopack#1 and #2, which are on higher side. The recommended level for such unit is about 30%. By maintaing this level, a saving of 16.6 KL of LDO or Rs. 2.66 lac would be achieved.

Possibility of installing the heat recovery unit is also explored for both the thermopacks but it is feasible for #1 only, due to less operating hours. The possible savings for thermopack#1 in this regard is about Rs. 0.65 lac with a pay back period of 20 months.

Ovens

Electrical oven#2

A detailed heat balance is worked out for this oven and according to it the useful heat, needed to heat components to 180°C, is 24.2%. It is recommended to replace electrical heating with thermic fluid heating which will bring in the savings of about Rs. 2.4 lac after offsetting the additional LDO consumption needed for components heating.

The temperatures of baths meant for the pre-treatment were measured to be higher by 2-7°C then the prescribed one. This is not a healthy practice and can result into higher consumption of energy. It is, therefore, recommended to maintain the temperatures in desired range to avoid any loss occurring on this account.

Powder coating oven

Efficiency of drying and baking chambers is calculated to be 72.71% and 58.89% respectively. Lower efficiencies are due to higher excess air and higher temperature of flue gas. Recommended excess air level for such burners are 30% and operating at this level 8.3 KL of LDO or Rs. 1.32 lac can be saved. Management is planning to replace these burners with new Italian (Riello) burners. It is suggested to maintaing the same (30%) excess air level in new burners to have the benefit of lower fuel consumption compared to Max burners. Heat recovery unit is not feasible, though the flue gas temperature is very high, because of very low operating hours.

Pumps

A combined flow of 100 m3/hr was measured against a designed installed capacity of 400 m3/hr for the soft water pumping system. Input power measurements revealed that at present the pumps were drawing 35 kW when operated in parallel. The value of input power was high for the system. The system parameters like head and flow for the same configuration can be achieved with a lesser energy consumption. Therefore replacement of the parallel pumping system with proper sized single unit would result in a savings of 2.56 lacs with an investment of 1.2 lacs.

Electrical systems

Demand management

- As the cost of electricity is less for DHBVNL supply, efforts should be made to draw maximum power from DHBVNL so that the total electricity cost is reduced. An analysis was done to identify the scope of increasing the power consumption from DHBVNL.
- Measurements were taken on transformer #4 to know the total running load on DHBVNL. It was found that total running load on DHBVNL supply is around 330 kVA having a scope of putting an additional load of around 100 kVA to increase the power consumption from DHBVNL.
- Non-critical continuous loads of spray line (57 kW) and Dip line (30 kW) can be put on DHBVNL supply.
- This will result in a saving of around 80 kVA x 0.85 p.f. x 5 x 4 x 26 = Rs 35,000 per month (Rs 4.24 lacs per year) without any investment.

Transformers

- Loading on transformers was established by taking measurements on each main feeder
- Transformers are loaded in the range of 33 – 36% of rated capacity. The transformers are designed to have maximum efficiency at 33% of the rated capacity. So loading of all the transformers is satisfactory.

Power factor

- Power factor measurements were done on all main feeders inside the plant. This exercise was done to analyse the present power factor scenario and to formulate the compensation scheme for power factor improvements.
- Condition of capacitor banks was checked to know the exact kVAR being supplied by the capacitors in the system.
- Total 22 capacitor banks were tested. It was found that two capacitor banks were supplying less kVAR as compared to their rated value. It is therefore recommended to replace these capacitor banks with new ones and also check capacitor banks periodically and replace them whenever their value deteriorate less than 50% of the rated value.
- As the load on transformers number 2, 3 and 4 is of variable nature and permanent connection of capacitor banks causes overcompensation. A power factor variation of transformer number 2 was recorded. Figure 4.5.3 shows the variation of power factor of transformer no.2 for a period of 10 minutes. It can be observed that variation in power factor is very fast and most of the time it is leading. Also, installation of air contactor type relay on these transformers will cause frequent shuttering of the contactor. Therefore, it is recommended that a thyristor controlled capacitor banks be installed to improve the power factor for transformers feeding such variable loads. A brief write up on thyristor controlled capacitor banks is given in Annexure 4.2. The cost of 25 and 50 kVAR thyristor controlled capacitor banks is Rs. 43,650 and Rs. 53,000 respectively.

Lighting

- Lighting level was measured at several sections of the plant during day and night time.
- It was found that generally the illumination provided is adequate in various sections of the plant.

- It was found there are 16 tube lights in the old store area of the plant for two task tables. The illumination level measured during day time showed a level of 72 lux which is within the range of BIS recommended value of 50-100 lux. Since only two task desks have been provided in this area, there is a possibility that few lamps out of total 16 can be kept switched off permanently during day time. This measure would result in a saving of Rs. 4000 per annum.
- It is recommended that lamps, which are kept switched on during night time, should be controlled through timer.
- By installing a 28 W energy efficient tube light in place of 36 W lamp, annual energy saving of approximately Rs 200 per lamp could be achieved. There are 200 number of 36/40 W fluorescent tube lights installed in the plant and if all tube lights are replaced with 28 W tube light, there would be a saving of Rs 47,000/- with a payback period of 3.1 years.
- Since the payback period is 3.1 years, one time replacement of all lamps is not justified. Therefore, replacement could be carried out whenever the presently installed lamps burn out.

Electric motors

To evaluate the performance of motors and to see how they are loaded, load tests were conducted on 8 motors. It can be seen from table 5.1 that motor loading varied from a low of 35% for new paint shop blower and to as high as 88% for PP6 (mechanical press).

To evaluate the operating efficiency of motors, tests were conducted under both load and no load conditions of motor. Based on the evaluation of performance parameters of the motors tested, the possibilities of replacing old and inefficient motors were studied. It was found that in spite of low efficiency levels in the presses, reduction of input energy should not be substantial to justify replacement because of the fluctuating nature of the operating load.

Using new and efficient motor in place of old inefficient ETP pump motor no-2 can save Rs 22,000. Investment for this replacement would be around Rs 35,000.

Compressed air systems

There are five numbers of air compressors operating in the plant. Two are of identical screw type, two identical reciprocating type and fifth compressor's type not mentioned. Four compressors were tested for the free air discharge (FAD). The designed FAD of each of the compressor no. 2,3 and 4, 5 is 5.66 m^3/min and 16.98 m^3/min respectively. The actual FAD of two sets of compressors is 2.97 m^3/min, 4.5 m^3/min and 16.33 m^3/min, 16.93 m^3/min respectively.

- The leakage rate in the compressed air distribution system was 30.4%. It was recommended to plug the leakage in the compressed air line. It offers significant energy savings with very small investment. Annual energy savings of 70200 kWh or Rs 3.15 lacs was estimated during the third trial. The average monetary saving rate was estimated to be Rs 59/- per hour.
- The leakage rate in fourth trial (in-house) is calculated to be 45.4%. Annual energy savings of 121970 kWh or Rs 5.11 lacs can be achieved without investment. The average monetary saving rate would be Rs 101/- per hour.

Cooling towers

There are two numbers of cooling towers operating in the plant to meet the cooling water requirement of Compressors, Press shop and 100 spot welders in Weld shop. The cooling towers are single cell round bottle shaped counter-flow induced draft type.

- Ensure proper maintenance of the existing fills of cooling towers to avail maximum water exposed surface area to air. It offers excellent level in the performance.

Solar thermal energy

Techno-economic feasibility of solar thermal application in the plant was worked out and found suitable for installing solar water heater for canteen. Implementation of this recommendation will bring in the savings of Rs. 2.04 lac per annum with an investment of Rs. 5.85 lac with a simple payback period of about 2.85 years.

Summary of recommendations

Sl. No.	Suggested measure	Total annual savings (Rs Lacs)	Investment (Rs Lacs)	Payback period (years/months)
1	Reduction of excess air in thermopacks	2.66	-	Immediate
2	Heat recovery in Thermopack#1	0.65	1.1	27 months
3	Replacing electrical heating with thermic fluid heating	2.4	Nominal	Immediate
4	Excess air reduction in powder coating oven's burners	1.32	-	Immediate
5	Replacement of parallel pumping system with proper sized single unit	2.56	1.2	5.6 months
6	Electrical systems demand management	4.24	Nil	Immediate

7	Installing 28 W energy efficient tube light in place of 36 W lamp	0.47	1.5	3.1 years
8	Replacing old inefficient ETP pump motor no.2 with new and efficient motor	0.22	0.35	1.5 years
9	Plugging of compressed air leakages in the distribution lines	3.15 (3rd trial) 5.11 (4th trial)*	Nil	Immediate
10	Installation of solar water heater for canteen	2.04	5.85	2.85 years
	Total	19.71	9.91	

* Not considered in the total saving

1

Thermic fluid heaters (Thermopacs)

The plant has two identical LDO fired, forced draught, down fired thermic fluid heaters, supplied by Thermax. The capacity of each thermopac heater is 6 lakh-Kcal/hr. Thermopac#1 caters to spray oven and spray line pre-treatment whereas the thermopac#2 caters to dip line pre-treatment for electrical oven and pre-treatment for powder coating oven. The design details of the thermopacs are given in table1.0.

Table1.0 Design details of Thermopacs

Design parameters	
Capacity (kcal/hr)	6,00,000
LDO consumption (kg/hr) (with GCV of LDO=10,700 kcal/kg)	68.4
Thermic fluid in circuit (lit.)	351
Thermic fluid flow (lit./hr)	30,000

The actual supply and return hot oil temperatures were observed to be 270/220°C and 190/160°C respectively in thermopac#1 and #2. However, the set supply and return hot oil temperatures are 290/220°C and 205/160°C respectively for thermopacs#1 and #2. Both the machines are given on operational contract.

Combustion air at ambient temperature is supplied by FD fan which can be controlled by movement of damper. The average fuel consumption (LDO), on the basis of recent two month's data, is about 56 and 54 litres per hour for Thermopac#1 and #2 respectively. Fuel consumption is measured by putting oil flow meter on fuel supply line occasionally. The following sections discuss the methodology adopted for evaluating the Thermopacs performances and various measurements taken for calculating the efficiency and associated losses.

1.1 Performance of the heater

The performance of the heater can be assessed by determining the thermal efficiency. The thermal efficiency is determined by indirect method, on the basis of various losses occurring in the heater. To arrive at the efficiency, various losses associated with Thermopacs are calculated. Few values (like stoichiometric air requirement, moisture and hydrogen content of the fuel, etc) are taken from the handbook. The parameters measured/collected from the plant to evaluate the thermal efficiency are given below.

- Oxygen percentage in flue gas
- Flue gas temperature
- Carbon monoxide level in flue gas
- Combustion air temperature
- Ambient condition

1.1.1 *Heat losses*

As a part of efficiency evaluation by indirect method, a detailed heat balance was carried out which is enclosed in Annexure 1.1. The summary of the results of the heat balance as evaluated by indirect method, is given in Table 1.1.1.

Table 1.1.1 Heat balances of Thermopacs

S No	Type of heat loss (in %)	*Thermopac#1*	*Thermopac#2*
1.	Dry flue gas loss	15.32	10.25
2.	Loss due to hydrogen and moisture in fuel	7.23	6.93
3.	Loss due to moisture in air	0.71	0.47
4.	Structural loss	0.93	0.93
5.	**Total heat loss**	24.19	18.59
6.	**Thermal efficiency**	75.81	81.41

It is clear from the above table that the efficiencies of the Thermopacs are 75.81% and 81.41%, which could be improved further by implementing the following suggestions.

1.1.2 *Dry flue gas loss*

The dry flue gas loss of Thermopacs is calculated to be 15.32% and 10.25% respectively, which is highest among all the losses, calculated and tabulated above. Therefore, this loss needs an in-depth study. The stack loss depends directly on the percentage of excess air and flue gas exit temperature. These two factors, if taken care of, can reduce this loss substantially.

1.1.2.1 Excess Air Level

Every fuel needs a specified quantity of stoichiometric air for its combustion. In actual practice, since, mixing of fuel with air is never perfect, a certain amount of excess air is always needed to complete the combustion and ensure the release of entire heat contained in the fuel. Too much of air results in excessive heat loss as the superfluous air does not take part in combustion but carries away valuable heat to the atmosphere from the furnace. Besides, surplus air lowers the furnace temperature and thereby the overall heat transfers rate, and hence results in lower combustion efficiency.

Likewise if the excess air is too less than the optimum quantity, combustion would be in-complete resulting in the formation of gases like carbon monoxide etc, in the flue gas. The maximum permissible limit for CO is 0.1%. Above this, loss due to CO formation is much higher than the benefit availed on account of lower excess air level.

The importance of maintaining optimum level of excess air is evident from the above discussion. The recommended quantity of excess air for these heaters is 20-30% considering the their age also.

The quantity of excess air, during the energy study, was found to be 96% and 79% in Thermopac#1 and #2 respectively, which is on higher side. It is recommended to operate both the boilers at 20-30% of excess air level. Attempts were made to reduce excess air level during the energy audit but it couldn't be brought in desired range in both the thermopacs. In thermopac#1, it was reduced to 63% from 96% whereas in thermopac#2 it is reduced to 53%. In thermopac#1, even after closing the damper fully excess air level couldn't be brought below 63%. It is because of de-shaping of the damper and because of this fan opening does not close tightly, though the damper is closed fully. In thermopac#2, reduction of excess air below 53% generated lot of unburnts in the form of CO formation. It is suggested to replace the existing damper with the new one in thermopac#1 and clean thoroughly/replace the existing burner to attain the lower excess air in prescribed limit. Improvement in thermopac efficiency due to maintaining the excess air level at or below 30% in flue gas is indicated in table1.1.2.1.

Table 1.1.2.1 improvement in efficiency

Thermopac	Current excess air in flue gas (%)	Efficiency with current excess air level (%)	Efficiency with 30% excess air level (%)	LDO savings per annum (KL)	Monetary savings (Rs. Lakh)
Thermopac#1	96	75.81	80.94	11.8	1.89
Thermopac#2	79	81.41	84.19	4.8	0.77

Excess air can be reduced by closing the damper opening of FD fan. The correct opening can be adjudged by checking O_2% in the flue gas. For optimum operation it should be in a range of 3-5%. Total savings due to this will be 16.6

1.1.5 Structural loss

The structural losses in both the Thermopacs are calculated to be 0.93% which is well within the limits.

1.1.6 Heat duty of thermopacs

It is worked out with the current fuel consumption and efficiency of thermopacs, that the heat delivery is only about 3.7 lakh kcal/hr (62% of design capacity) and 3.8 kcal/hr (64% of design capacity) for thethermopac#1 and #2 respectively. The spare capacities available with thermopacs#1 and #2 are 2.3 lakh kcal/hr and 2.2 Lakh kcal/hr respectively. This extra capacity available could be utilised for heating the component in electrical oven.

2

Ovens

Two ovens are covered in this study as per the scope. These ovens are electrical oven and powder coating oven.

2.1 Electrical Ovens

Plant is equipped with two electrically heated box type ovens out of which only one operates and other one is kept closed. Voluminous or odd shaped components are dried in it after painting. It, generally, operates seven hours a day. Normally 13 batches are dried in it. The retention time is 30 minutes per batch. However, first batch takes about one hour as the oven is heated from the cold conditions. Each batch is electrically heated up to 180°C and then the batch is brought out. Connected heating load of the oven is 50 kW and there is a blower at the top of the oven to create the convection currents for heat transfer to the components.

2.1.1 Heat balance

Heat balance of the oven can be prepared by calculating the useful heat i.e. the heat required to attain the temperature of 180°C and various heat losses taking place in the oven. It is calculate based on the average of one week's data during which the energy audit study was carried out. The data such as number of batches, type, weight and numbers of component going in to the oven, etc were collected and a detailed heat balance is prepared, which is summarised in table 2.1.1 below.

Table 2.1.1 Heat balance of electrical oven

Components	%
Heat required to heat the components	24.20
Heat absorbed by trolley and hanger*	8.18
Heat absorbed by exhaust air$	14.56
Surface heat losses	33.14
Unaccounted #	19.91
Total	**100**

* weight of trolley and hanger is assumed to be 100 kg

$ exhaust is assumed to be 5% of the circulation fan flow which is calculated assuming the head generation of 250 mmwc by the circulation blower, in the absence of data

Includes heat loss to hearth, heat stored in oven body, heat required to evaporate solvent vapours, etc

It is clear from the table that the useful heat, to heat the components to 180°C, is only about 24.2% and remaining energy is lost in the process of heating. Biggest heat loss is due to surface heat loss. Though, the average surface temperature was found to be low (54°C), it is high because of large surface area. Please refer the Annexure 2.1 for details.

2.1.2 *Replacing the electrical heating in the oven by thermic fluid heating*

During the study it was observed that both the thermopacks are operating at part capacity (less then 65%). It is suggested to utilise the available capacity of thermopacks for heating the components in electrical oven and replace the electrical heating. Considering the age of the thermopacks and assuming that they will not able to deliver more then the 80% of their design value, even the available 15% capacity of one thermopack (or 90,000 kcal/hr) would be more then the requirement of the electric oven. Each oven is equipped with 50 kW electrical heater, which corresponds to thermal heat requirement of 43000 kcal/hr only. Oven would need some modification, as electric heaters have to be replaced with thermic fluid coils. Because of this switch over the batch time may increase a little but it would not be the problem as the oven operates only 7/8 hours a day.

The capacity of the thermopacks can be increased by resetting the temperature of supplying/return fluid oil. Thermopack suppliers may be contacted if the plant experiences any problem in increasing the capacity. Replacing by thermal heating will result in the savings of Rs. 2.4 lakh after off setting the cost towards increased LDO consumption in thermopacks as calculated in Annexure 2.2.

Plant personnel also have the idea to replace electrical heaters with LDO fired burner. Thermal heating is always economical compared to electrical heating. Since, expected increase in LDO consumption will be about 42 kg/day, if above recommendation is implemented, availability of such a small efficient burner has to be ensured before taking any further step.

2.1.3 Higher bath temperature

During the study, the bath temperatures for pre-treatment of components were measured to be 2-7°C higher then the prescribed temperature which is written on the boards hanging over the each respective bath. This is not a healthy operating practice and lead to high energy consumption. The equivalent LDO loss, due to this, is 0.31 lit per day for one tank having the open surface area of 3.5 m^2. This factor is for raising the temperature by 1°C of one ton of water through which one ton of components is passing per day. Loss of fuel in actual working condition, in various combinations, is calculated in table 2.1.3. The basis of calculation is given in Annexure 2.3. It is recommended that the bath temperatures should be maintained in the stipulated range and any over heating may be avoided.

Table-2.1.3 Loss due to high bath temperatures

Tons of water per tank	No. of tanks	Temperature rise above the prescribed limit (°C)	Tons of components passed through per tank	Loss of LDO per annum (lit.)	Monetary loss per annum (Rs. Lakh)
1	1	1	1	93	0.015
2	2	2	2	1490	0.24
3	3	3	3	7542	1.40
3	4	3	3	10057	1.61

2.2 Powder coating ovens

Plant is equipped with one powder-coating oven which has two separate chambers for 1) drying and 2) baking. In this oven components are coated with water based paints which is dried in drying oven and then it goes to baking oven for paint stabilisation. The temperature of the drying chamber is maintained about 120°C whereas the baking is done at 180°C. Both the chambers have LDO fired heating system and are equipped with the modulating type burners supplied by Max-USA. The maximum capacity of the baking burner is 6,68,680 kcal/hr whereas the same of drying chamber burner is 3,22,890 kcal/hr. Both the burners require LPG fired pilot flame. Fuel flow through the burner is linked with the temperature of the chambers. As the temperature in the chamber approaches to the set temperature, fuel flow through the burner reduces.

Combustion air at ambient temperature is supplied to the burner which gets regulated automatically with the fuel. The average fuel consumption (LDO) is about 15 and 29 litres per hour for drying and baking burners, respectively. Fuel consumption is measured by putting oil flow meter on fuel supply line occasionally. The following sections discuss the methodology adopted for evaluating the performances and various measurements taken for calculating the efficiency and associated losses.

2.2.1 *Performance of the drying and baking ovens*

The performance of the oven can be assessed by determining the thermal efficiency. The thermal efficiency is determined by indirect method, on the basis of various losses occurring in the heater. To arrive at the efficiency, various losses associated with ovens are calculated. Few values (like stoichiometric air requirement, etc) are taken from the handbook. The parameters measured/collected from the plant to evaluate the thermal efficiency are given below.

- Oxygen percentage in flue gas
- Flue gas temperature
- Carbon monoxide level in flue gas
- Combustion air temperature
- Ambient condition

2.2.1.1 Heat losses

As a part of efficiency evaluation by indirect method, a detailed heat balance was carried out which is enclosed in Annexure 2.4. The summary of the results of the heat balance as evaluated by indirect method, is given in Table 2.2.1.1.

Table 2.2.1.1 Heat balances of ovens

S No	Type of heat loss (in %)	*Drying*	*Baking*
1.	Dry flue gas loss	17.42	29.69
2.	Loss due to hydrogen and moisture in fuel	6.99	7.98
3.	Loss due to moisture in air	0.82	1.38
4.	Structural loss	1.0	1.0
5.	**Total heat loss**	26.23	40.05
6.	**Thermal efficiency**	73.77	59.95

It is clear from the above table that the efficiencies of the ovens are 73.77% and 59.95%, which could be improved further by implementing the following suggestions.

2.2.1.2 Dry flue gas loss

The dry flue gas loss of ovens is calculated to be 17.42% and 29.69% respectively, which is highest among all the losses, calculated and tabulated above. Therefore, this loss needs an in-depth study. The stack loss depends directly on the percentage of excess air and flue gas exit temperature. These two factors, if taken care of, can reduce this loss substantially.

2.2.1.2.1 Excess Air Level

The quantity of excess air, during the energy study, was found to be 188% and 128% in drying and baking ovens respectively, which is very high. It is recommended to operate both the boilers at 20-30% of excess air level. It can be done by changing the fuel air ratio on modulating rod which controls the valve openings for fuel and air. Improvement in thermopack efficiency due to maintaining the excess air level at or below 30% in flue gas is indicated in table 2.2.1.2. 1. Since the operating hours of these ovens are low (one shift a day and 150 days a year), savings are also low though there is a significant improvement in efficiency.

Table-2.2.1.2.1 Improvement in efficiency

Oven	Current excess air in flue gas (%)	Efficiency with current excess air level (%)	Efficiency with 30% excess air level (%)	LDO savings per annum (KL)	Monetary savings (Rs. Lakh)
Drying	188	73.77	83.86	2.1	0.33
Baking	128	59.95	72.77	6.1	0.99

It is suggested that plant may purchase a flue gas analyser and maintain the excess air in a range of 20-30% (corresponding to oxygen level of 5%). Total savings due to this will be 8.2 KL of LDO or Rs. 1.32 lakh per annum as shown in table2.2.1.2.1. Please refer Annexure 2.5 for details.

Plant is also planning to replace these burners with new Riello burners which are of Italian make. It is recommended that similar excess air can also be maintained in these burners which will reduce the fuel consumption compared to existing situation.

2.2.1.2.2 Flue gas exit temperature and heat recovery

The flue gas temperatures after the chambers were measured to be 201°C and 395°C in drying and baking oven respectively, which is on higher side, particularly in baking oven. Possibilities of heat recovery unit is also worked out for these ovens but due to very low operating hours, it is not found to be feasible as the pay back period is over four years.

2.2.1.3 Loss due to Moisture in air

This loss is because of moisture content in air, which depends on the relative humidity and the ambient temperature. The other controllable factors, on which this loss depends, are excess air level and flue gas temperature. Presently, this loss is calculated to be 0.82% and 1.38% in drying and baking oven, respectively. By reducing the excess air level in a range of 20-30% this loss will come down to 0.37% and 0.79% in drying and baking oven, respectively.

2.2.1.4 Loss due to Hydrogen and Moisture in fuel

This loss depends upon the moisture and hydrogen content of the fuel and flue gas exit temperature. The moisture and hydrogen content of the fuel is fixed and, therefore, the only controlling factor is the exit flue gas temperature. The loss due to hydrogen and moisture is worked out to be 6.99% and 7.98% in drying and baking oven, respectively.

2.2.1.5 Structural loss

The structural loss in both the ovens is calculated to be 1%, which is well within the limits.

3

Pumps

Energy audit of pumps was carried out to determine the operating energy performance of pumps and identify measures for improving the same. The rated parameters of the pumps have been given in table 3.0.

Table 3.0 Rated parameters of the water pump

Sno	Rated Head (Metres)	Rated Capacity (M3/Hr)	Rated kW of the motor	RPM
1	59.5	200	22	2955

3.1 Energy audit of water pumps

3.1.1 Pump efficiency

The efficiency of the pump is simply the ratio

$$= \quad P_{out}/P_{in}$$

which is usually expressed as percentage. This efficiency is found to be a function of the flow rate, and is therefore not just a constant for a given pump. Efficiency is an important characteristic of a pump, since, as indicated in Figure 3.1.1, the difference $P_{in} - P_{out}$ represents power that is lost.

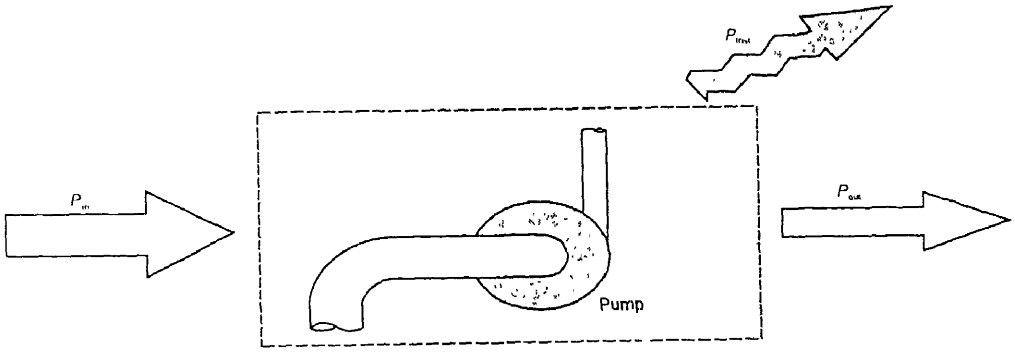


Figure 3.1.1 Schematic of input and output power

3.1.2 Input power

The output power of the motor, which is assumed to be equal to the input power (sometimes called the brake horsepower) to the pump, is given by

P_{input} = input power of the motor x efficiency

3.1.3 Output power

The output power (sometimes called the *fluid power*) of the pump P_{out} is equal to the rate of work done on the fluid, namely

$$P_{out} = \gamma Q h_p,$$

Where γ is the specific weight of the fluid, Q is the volumetric flow rate, and hp is the energy increase per unit weight, or pump head, supplied to the fluid between inlet A and out B of the pump (Figure 3.1.3).

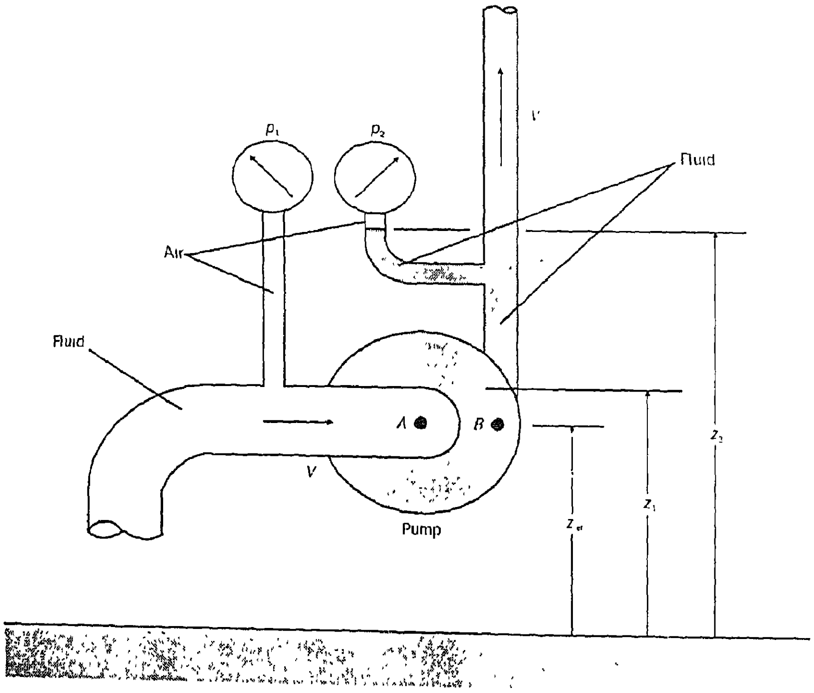


Figure 3.1.3 Interpretation of elevation z_1 and z_2

$$\left[\frac{p}{\gamma}+\frac{V^2}{2g}+z\right]_A + h_p = \left[\frac{p}{\gamma}+\frac{V^2}{2g}+z\right]_B$$

Since A and B are at the same reference height z_{ref}, this expressions simplifies to

$$h_p = \frac{P_B - P_A}{\gamma} + \frac{V_2^2 - V_1^2}{2g}$$

Where, the entrance velocity is *V1* and the exit velocity is *V2*. In the present case, the inlet and outlet pipe were almost same, *V1* and *V2* will be equal, then

$$h_p = \frac{P_B - P_A}{\gamma}$$

3.1.4 *Computation of the efficiency of the pumps*

The Flow rate of the pumps was measured with water flow meters. The discharge pressures were noted down from their meters, input power to the motor was measured by power analysers. The efficiency of the motor was computed from load and no load test performed on the motors and the efficiency of pumps is calculated by using the formulas given in previous sections 3.1.1 to 3.1.3.

Measured head = 40 m
Measured flow = 75m3/Hr
Hyhraulic power = 8.6 kW
Motor input power = 17.8
Efficiency of the motor = 86%
Input (kW) to the pump = 16.02
Efficiency of the pump = 56 %

3.2 Cooling water system performance

Schematic diagram of the cooling water system is shown in figure 3.2. Water from the storage tank is pumped through various process equipments like welding machines, Air compressors etc. by two parallel pumps of capacity 200m3/Hr. The heat picked up by the cooling water is transferred to the cooling tower. The cooled water is then pumped back to the storage tank.

Measurements of various parameters like flow, pressure, input power was carried to analyse the performance of the existing system. The following observation was made

- A combined flow of 107 m^3/hr was measured against a designed installed capacity of 400 m^3/hr. It was revealed during discussion that the impellers of both the pumps were trimmed during the time of installation resulting in the reduction in the rated flow.
- Input power measurements revealed that at present the pumps were drawing 35 kW when operated in parallel. The value of input power was high for the system. The system parameters like head and flow for the same configuration can be achieved with a lesser energy consumption.

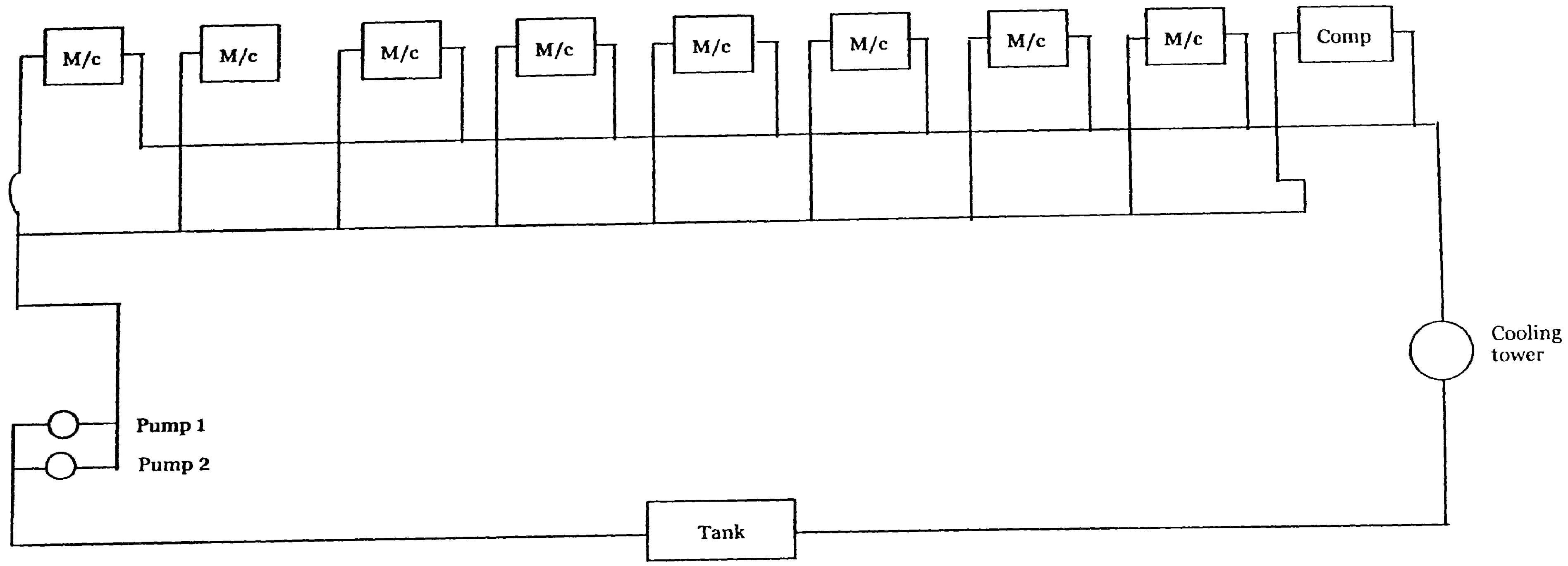


Figure 3.2 Cooling water system

During the recess period. It was observed that the both the pumps were being operated. While it was observed that the water requirement for cooling the compressors can be met by running a single pump. Therefore one of the pumps can be switched off during recess hours.

3.2.1 Modification in the cooling water system.

The schematic of the modified system is given in figure 3.2.1. It is recommended that the pump be replaced with a new pump of 120 m^3/h and head of 60 m (assuming operation head and flow same as designed head and flow). With this modification there would be a reduction of about 8.6 kW of input power. The investment for such modifications would be about Rs 120,000/-. This amount shall be paid back in 5.6 months. Details of computation of energy saving is given in table 3.2.1.

Table 3.2.1 Computation of energy saving in cooling water system

Existing operation	
Pump head	59 M
Pump Flow	200 M3/HR
Motor kW	22 KW
Measured flow	107 M3/HR
Measured head	50 M
Measured power	35 KW
Proposed operation	
Pump head	60 M
Pump Flow	120 M3/HR
Motor kW	37 KW
Predicted operation	
Pump head	50 M
Pump flow	107 M3/HR
hydraulic power	14.6 KW
Pump eff	0.65
Pump input	22.4 KW
Motor eff	0.85
Motor input	26.4 KW
Savings	8.6 KW
Units	46656 KWh
Monetary	256609 Rs
Investments	120000 Rs
Expected payback period	5.6 Months

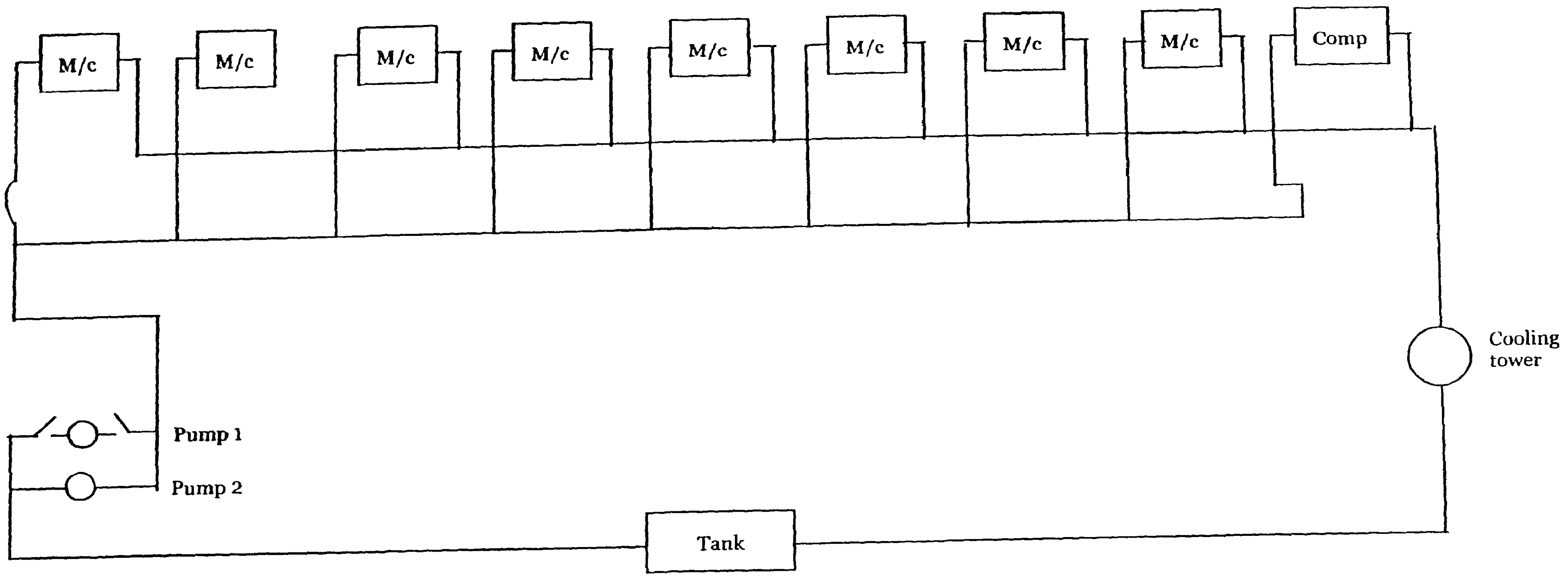


Figure 3.2.1 Modified cooling water system

4 Electrical Systems

4.1 Electricity distribution

There are two sources of power supply to the plant, one is the Dakshin Haryana Bijli Vitran Nigam Ltd. (DHBVNL) and second Maruti Udyog Limited (MUL) situated in the Maruti J.V.Complex itself. The power supply is available at 11 kV, which is stepped down to 0.415 kV through 4 main transformers of 1000 kVA rating each. The loads connected to 3 main transformers out of four (Trf no.1, 2 and 3) are fed from MUL power supply. While the loads connected to fourth transformer (Trf. no.4) are normally fed from DHBVNL grid supply and MUL power supply is kept as standby to take loads in case of DHBVNL power failure. The single line diagram showing distribution system of the plant is presented as Annexure 4.1.

4.2 Tariff structure

The total connected load of the plant is 4.7 MW. The plant has a contract demand of 500 kVA with DHBVNL. The power billing from DHBVNL is based on electricity consumption during the billing period and there is a minimum monthly charge of Rs. 1 lakh in case of less power consumption. The unit electricity rates for the plant are about Rs. 4.09.

As per tariff structure with MUL, the electricity billing is also based on energy consumption and presently it is charged at a rate of about Rs.9.0 per kWh. There are no demand charges for electricity consumption from either of the power supply source.

4.3 Demand Management

The contract demand of the plant is 500 kVA with DHBVNL. As presently the cost of electricity is less for DHBVNL supply, efforts should be made to draw maximum power from DHBVNL so that the total electricity cost is reduced. An analysis was done to identify the scope of increasing the power consumption from DHBVNL. The monthly maximum demand recorded on DHBVNL was not available because of faulty energy meter. Therefore, measurements were taken on transformer number #4 to know the total running load on DHBVNL. The details of the measurements are given in Table 4.3a. It can be seen from table that total running load on DHBVNL supply is around 330 kVA. Thus, there is a scope of putting an additional load of around 100 kVA to increase the power consumption from DHBVNL. Discussion with plant personnel revealed that non-critical continuous loads of Spray Line (57 kW) and Dip Line (30 kW) can be put on DHBVNL supply, which will make a total load of around 450 kVA on transformer#4. It is, therefore, recommended that an additional load of around 100 kVA be put on transformer #4, which will result in a saving of around Rs. 4.24 lakhs per annum (assuming a power availability of 5 hours from DHBVNL) without any investment.

Table 4.3a Loading on transformers

		Measured			
Transformer #	Connected load (excluding lighting load) (kW)	KW	KVA	Loading (%)	Efficiency (%)
Trf #1	938	356	360	36	99.2
Trf #2	1184	270	342	35	99.2
Trf #3	1643	270	342	35	99.2
Trf #4	612	292	330	33	99.2

4.4 Transformer

There are 4 transformers installed, 1000 kVA rating each, to step down the incoming power supply at 11 kV to 0.415 kV. All the four transformers are kept on load under normal operating conditions. Two (trf. no-2&3) out of four transformers supply power to all the welding machines installed in the plant and rest of the plant loads are put on other two transformers (trf. no-1& 4). The transformer details along with the associated design losses are summarized in Table 4.4a. It can be calculated from the design data available in test certificates that these transformers have been designed to have peak efficiency of 99.22 % at 327 kVA load of 0.9 power factor.

Table 4.4a Classification of transformers

Capacity (kVA)	Number	Voltage ratio (kV)	Designed losses (W)		Calculated load for maximum efficiency	
			Iron loss	Cu loss	KVA	%
1000	4	11/0.415	1152	10771	327	33

Loading of transformers is not recorded, as there is not much variation in the load of each transformer throughout the day. Thus, the loading on transformers was established by taking measurements on each main feeder (Table 4.3a). It is clear from the table that present operating point of all the transformers is near the point of maximum efficiency. It was measured that the transformer no.1 was loaded to a maximum load of 360 kVA and transformer no.4 to a load of 330 kVA. Corresponding to these loads, transformer no.1 and 4 were loaded upto 36% and 33% of their rated capacity respectively. At these loading, it was worked out that all transformers are operating at their peak efficiency of 99.22% at 0.9 power factor.

4.5 Power Factor

The line current drawn by induction motors, transformers and other inductive devices consists of two components; the magnetizing current and the power producing current. The magnetizing current is required to produce the magnetic flux in the machine. This component of current creates a reactive power compensation which is measured in kilo-volt-amperes reactive (kVAR). The power producing current is that current which reacts with the magnetic flux to produce the output torque of the machine. This component of current creates the load power requirement measured in kilowatts (kW). The magnetizing current and magnetic flux are relatively constant at constant voltage. However, the power producing current is proportional to the load torque requirement. The magnetizing current is essential for transferring power through the core of a transformer or across the air gap of an induction motor. The magnetizing current lags the voltage by 90 degrees. The total current drawn by the machine is the vector sum of this reactive current and the power producing current. The power factor is defined as the cosine of the angle between the total current and power producing current vectors.

Low power factor leads to poor system efficiency as the high reactive component associated with low power factor gives rise to additional generating losses throughout the system. An improvement in power factor leads to:

- Reduction of load on transformers and distribution equipment,
- Reduction in load losses in transformers, distribution cables and other equipments resulting in a direct saving of kWh power consumption,
- Stabilization of the system voltage.

4.5.1 *Present power factor scenario*

To analyze the present power factor scenario of the plant, monthly data of average power factor was collected from the electricity bills for a period starting from January'02 to September'02. Table 4.5.1a gives the power factor during the period. It could be seen from the table that the average monthly power factor of the plant was above 0.88.

Table 4.5.1a Monthly average power factor of the plant

S.No.	Month	Power factor
1	January'02	0.92
2	February'02	0.93
3	March'02	0.93
4	July'02	0.92
5	August'02	0.88
6	September'02	0.99

A compensation scheme has been devised by Mark Auto to improve the overall power factor by installing capacitor banks at the sub-station. The installed capacity of such capacitors is given in Table 4.5.1b. Further, automatic power factor correction relay has also been installed on transformer # 4 at the sub-station.

Table 4.5.1b Details of capacitors installed

S.No.	Location	Total (kVAR)
1	Trasformer-1	390
2	Transformer-2	280
3	Transfromer-3	280
4	Transformer-4	380

4.5.2 *Power factor measurements*

Power factor measurements were done on all main feeders inside the plant. This exercise was done to analyze the present power factor scenario and to formulate the compensation scheme for power factor improvements. The results of the measurements are shown in Table 4.5.2a. These power factor readings are corresponding to the loads, which were operating at the time of taking measurements.

Table 4.5.2a Power factor measurements on main bus-bars

			Power Factor	
S.No.	Trf #	Load (kW)	With capacitor banks off	With capacitor banks on
1	Trf-1	356	0.75-0.8	0.99 (with all cap. on)
2	Trf-2	270	0.66-0.79	1 (with 50 % cap. on)
3	Trf-3	270	0.46-0.79	1 (with 50 % cap on)
4	Trf-4	292	0.81-0.83	0.83 (with APFCR)

Condition of capacitor banks was also checked to know the exact kVAR being supplied by the capacitors in the system. These measurements are presented in Table 4.5.2b.

Table 4.5.2b Condition of capacitors (System Voltage: 422 Volts)

S.NO.	Item	Phase Current (Amps)			Capacitor Capacity	
		I1	I2	I3	Rated	Delivering
Capacitor banks connected to transformer-1						
1	Capacitor bank-1	45	48	50	45	35
2	Capacitor bank-2	62	61	61	50	45
3	Capacitor bank-3	59	58	58	50	43
4	Capacitor bank-4	8	8	10	50	6
5	Capacitor bank-5	8	7	9	50	6
6	Capacitor bank-6*					
7	Capacitor bank-7	51	53	56	50	39
8	Capacitor bank-8*					
9	Capacitor bank-9*	19	18	14	15	13
10	Capacitor bank-10	14	14	18	15	11
Capacitor banks connected to transformer-2						
1	Capacitor bank-1	57	56	54	40	41
2	Capacitor bank-2	64	63	64	50	47
3	Capacitor bank-3	63	62	63	45	46
4	Capacitor bank-4*				50	
5	Capacitor bank-5*				45	
6	Capacitor bank-6	53	45	58	30	38
7	Capacitor bank-7*					
8	Capacitor bank-8*					
9	Capacitor bank-9*					
10	Capacitor bank-10*					
11	Capacitor bank-11	21	20	21	20	15
Capacitor banks connected to transformer-3						
1	Capacitor bank-1	67	67	69	50	50
2	Capacitor bank-2*					
3	Capacitor bank-3	21	20	21	15	15
4	Capacitor bank-4	32	33	33	25	24
5	Capacitor bank-5	70	69	69	50	51
6	Capacitor bank-6	70	70	70	50	51
7	Capacitor bank-7	32	32	32	25	23
Capacitor banks connected to transformer-4						
1	Capacitor bank-1	68	70	68	50	51

* Capacitor bank was not connected or spare panel

It can be seen from table 4.5.2b that two capacitor banks were supplying less kVAR as compared to their rated value. It is therefore recommended to replace these capacitor banks with new ones and also check capacitor banks periodically and replace them whenever their value deteriorate less than 50 percent of the rated value.

4.5.3 *Compensation Scheme*

A compensation scheme has been devised by Mark Auto to improve the overall power factor by installing capacitor banks at the sub-station. The capacitor banks are connected manually on all transformers except on transformer no.1. An automatic power factor correction relay has also been installed on transformer # 4 at the sub-station. As the load on transformers number 2, 3 and

4 is of variable nature and permanent connection of capacitor banks causes overcompensation. A power factor variation of transformer number 2 was recorded using the instrument. Figure 4.5.3 shows the variation of power factor of transformer no.2 for a period of 10 minutes. It can be observed that variation in power factor is very fast and most of the time it is leading. Also, installation of air contactor type relay on these transformers will cause frequent shuttering of the contactor. Therefore, it recommended that a thyristor controlled capacitor banks be installed to improve the power factor for transformers feeding such variable loads. A brief write up on thyristor controlled capacitor banks is given in Annexure 4.2. The estimated cost of 25 and 50 kVAR thyristor controlled capacitor banks is Rs. 43,650 and Rs. 53,000 respectively.

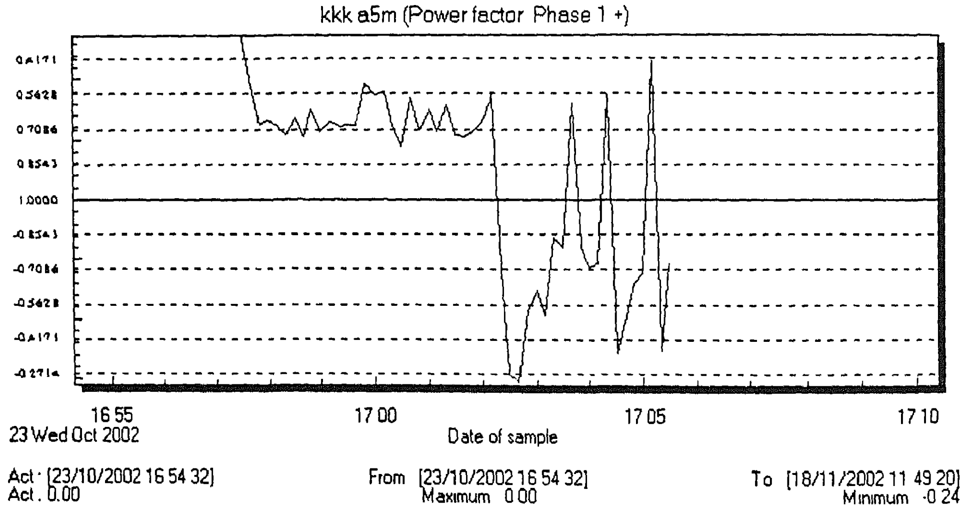


Figure 4.5.3 Power factor variation on transfer no.2

4.6 Lighting

Adequate and proper lighting contributes both directly and indirectly towards productivity and safety, and towards providing an improved work atmosphere. In fact, all these are inter-related and complimentary to each other. There are several factors, which contribute towards proper lighting, and it would be very difficult to deal with all of them when providing general illumination to a large area. However, all efforts were made to study and include these factors.

To study, analyze and identify energy conservation options in lighting, a study of the plant lighting load was conducted. This study included the lighting load in the plant as well as non-plant areas. The purpose of the study was to determine the lighting load and its distribution in various sections of the plant, determine the quality of illumination provided, and recommend measures to improve illumination and/or reduce electricity consumption.

A high quality and accurate digital "LICOR" lux meter was used to measure the illumination level at several sections of the plant during day time and night time also. Other performance indicators such as type of lamps used, type of luminaries, mounting height, physical condition of lamps and luminaries, use of day lighting etc. were also noted.

4.6.1 *Lighting Load*

It was found during the survey that mainly twin 36-W fluorescent tubes have been used in the closed rooms, offices and other non-plant area buildings while mercury vapour lamp of 80 W have been mainly provided in the plant areas. Street lighting is accomplished through high pressure sodium vapour (HPSV) lamps.

Based on the analysis of the data collected, the total installed lighting load of the plant works out to be about 90 kW (excluding ballast wattage) which forms about 2 per cent of the total connected load (4.7 MW) of the plant. This installed lighting load includes the lighting load of the main plant, utility, offices, stores, canteen, administrative and other buildings. Table 4.6.1a and Table 4.6.1b give the total installed lighting load for various areas of the plant and the total lighting load by the type of lamp used.

Table 4.6.1a Area-wise break-up of lighting load

S. No.	Area	Load (kW)	Percentage of total load
1	Press shop	12.7	14.5
2	Shearing and tool room	5.9	6.5
3	Weld shop-I	7.5	8.3
4	Weld shop-II	7.7	8.5
5	Axle line	6.0	6.6
6	New plant shop & final inspection	6.2	6.8
7	Old paint shop	5.2	5.7
8	DM plant & power house	5.6	5.9
9	Store	8.6	9.5
10	Quality control deptt.	0.2	0.2
11	Paint shop lab , Q C & finance	1.9	2.1
12	Purchase, PPC & MR atul swroop office	1.6	1.7
13	Design & canteen	4.6	5.1
14	Excise deptt & corporate office	12.7	14.1
15	Personal & gate	1.0	1.0
	Total	90	100.00

Table 4.6.1b Break - up of installed lighting load by type of lamp

Type of lamp	Number	Load (kW)	Percentage of total load
HPMV (80 W)	443	35	39
HPMV (125 W)	284	35	39
HPMV (400 W)	32	12	13
Fluorescent T.L. (20 W)	54	1	1
Fluorescent T.L. (36 W)	146	5	5
Fluorescent T.L. (40 W)	51	2	2
Incandescent bulb (100 W)	9	0.9	1
Total		90	100

It could be seen from table 4.6.1a that press shop, excise department and corporate lighting has the largest installed load of 25 kW and personal & gate has the least of 1 kW. Further non-plant area load forms only 14 percent of the total installed lighting load. It could be observed from table 4.6.1b that the mercury vapour lamps have found maximum use in the plant while incandescent bulb of 100 W the least.

4.6.2 *Illumination level*

The illumination level measured at different locations and the recommended level of lighting in these areas are given in table 4.6.2. The values separated by comma indicate illumination level taken at different places of the same area. The recommendations on required illumination level in most of the areas are taken from standard BIS values. The illumination required depends upon the difficulty of the task to be performed and varies widely.

It could be seen from the tables that generally the illumination provided has been adequate in various sections of the plant. Following sections detail out the various observations and recommendations made in various sections of the plant.

Table 4.6.2 Measured and recommended illumination level

Section	Average illumination level (lux)	
	Measured	Recommended
Power house	35*, 45*	100
Scrape yard	35	50-100
Compressor area	46, 48	50-100
Thermopac	20	50-100
DM Plant	79	50-100
ETP	21, 25	50-100
Old paint shop		
Dip Line	60, 80	100-150
Spray line	168	100-150

Section	Average illumination level (lux)	
	Measured	Recommended
Electric oven	72, 85	100
New paint shop		
Power coating line	282	100-150
Big burner	80*, 100*, 107	100-150
Spray booth	90	100-150
Small burner	115*, 125	100-150
Weldline-1	300*, 203	150-200
Weldline-2	275	150-200
Weldline-3	73	150-200
Final assembly & dispatch	464*, 604	200-350
Standard room	318*, 358*	350-400
Security room	135	100
Personal department	150*, 250*	100-150
Gas bank area	7	100
Bonded warehouse	450*, 78	100-150
Press shop	140	100-150
Tool room area	210	200-250
Semi-finished area	40	200-250
Old store (quality control lab)	72	50-100
Weld-1 Bought out component area	51	100
Weld-2 Bought out components	137	100
Production office	160*, 193*, 138	100
Accounts department	227	100-150

* Supplemented by day light

4.6.2.1 Old store area

A total of 16 number of fluorescent tube lights of 40 W each has been provided to illuminate this area. The illumination level measured during day time showed a level of 72 lux which is within the range of BIS recommended value of 50-100 lux. Since only two task desks have been provided in this area, there is a possibility that few lamps out of total 16 can be kept switched off permanently during day time. This measure would result in a saving of Rs. 4000 per annum.

4.6.2.2 Other Options

4.6.2.2.1 Time Switches

Time switches are the devices which can control the switching on time and period automatically for a variety of applications by sliding the segments of the in-built clock dial in and out. These devices, thus, save energy by keeping equipment in operation only when required.

The switching operation of all the outdoor lamps and the lamps required in night time are manually controlled. Manual control cannot always be reliably achieved unless it is regarded as part of the work of the employee. Automatic control of lights is much more effective at ensuring that the lights are switched on only when they are needed. Therefore, it is recommended that all the outdoor lamps and the lamps which are required in night time only should be controlled through time switches.

4.6.2.2.2 Energy Efficient Tube light

Presently slim tube lights of 28 W, 16 mm diameter shell are available in the country. These lamps consume about 20 percent less electricity as compared to the conventional fluorescent tube lights. Due to lesser shell diameter, the lamp also burns `brighter'. The life of E+ fluorescent lamp is higher then that for conventional lamps. The salient features of energy efficient tube light along with address of the supplier are given in Annexure 4.3. It is recommended that a batch of 10 lamps be replaced with energy efficient tube light and the savings and performance and reliability of the tube be ascertained. On being convinced of the reliability of the tube, it is recommended that all fluorescent lamps be replaced with energy efficient tube lights.

By installing a 28 W tube light in place of 36 W lamp, annual energy saving of approximately Rs 200 per lamp could be achieved. There are 200 number of 36/40 W fluorescent tube lights installed in the plant and if all tube lights are replaced with 28 W tube light, then

Reduction in lamp wattage (kW) : 3.6
Annual saving in energy (kWh) : 9504
(@ 8 hours of average operation
and 330 days of operation in a year)
Annual savings in energy charges (Rs.) : 47520
Investment required (Rs.) : 1.5 lakhs
Payback period (years) : 3.15

Since the payback period is 3.1 years, one time replacement of all lamps is not justified. Therefore, replacement could be carried out whenever the presently installed lamps burn out.

5

Electric Motors

The energy audit of motors installed in the plant was carried out to study analyse and identify the potential for energy conservation in motors. The study included motors installed in the process as well as in utility section of the plant. The study focussed broadly on the following two aspects, which have bearing on energy use efficiency of motors.

- Loading of motors
- Energy saving options

The details of the measurements taken and observation made about each of the above two aspects are detailed in the following sections.

5.1 Motor loading

Selecting a motor with correct horse-power rating for an application is usually difficult because of several constraints as outlined below.

- Lack of information on torque-speed characteristics of machines
- Possible deterioration in machine conditions with improper maintenance
- Possible changes in production process parameters

A simple solution to deal with many of these uncertainties is to play safe and over design i.e. select a motor of higher rating. This can result in power wastage apart from higher initial cost. This, however, does not imply replacement with motor of small ratings, as it may not lead to any savings in certain cases, because of much lower efficiency of smaller motors. To evaluate the performance of motors and to see how they are loaded, load tests were conducted on 8 motors. Care was taken to record the peak load on the motors (wherever it was practically feasible) to decide the extent of over or under loading. Table 5.1 gives the result of load test conducted on motors during the field study.

Table 5.1 Motor loading

	(Measured)			(Rated)		
Application	Voltage	kW	Current A	kW	Current A	Loading
PP3*	421	62	62.7	45	78	85.35
HMT-1* (was not near peak load)	411	11	70.5	90	147	8.20
ETP Pump	405	13.3	24.2	15	27	71.05
New Paint shop Blower	405	15.1	33	37	65	35.76
Soft water pump	407	17.8	28.3	22	37	69.50
PP6*	421	62	62.7	45	78	88.16
PP7*	407	8	14.7	11	20	62.35
Screw compressor	404	102	164	110	180	82

* Mechanical presses - exhibited variable loading

It can be seen from this table that motor loading varied from a low of 35% for new paint shop blower and to as high as 88% for PP6 (mechanical press).

To achieve the best design efficiency and power factor values, it is recommended that motor should be loaded in the range of 70-90 percent of the rated power. Some of the salient observation made during the study on electric motors are

- Oven recirculation fan exhibited lower loading when it was recirculating hot air while it exhibited higher loading with cold air.
- Measured Peak loads for the mechanical presses was in the range of 60 - 80% of the rated capacity of the motor.

Out of the motors audited, no over sized motors that can be replaced by a low rated motors were found.

5.1.1 Other options

5.1.1.1 Efficiency checking

To evaluate the operating efficiency of motors, tests were conducted under both load and no load conditions of motor. These tests were conducted using a portable digital power meter, digital non-contact type tachometer and other instruments. A total of 7 motors were tested to determine the operating performance. Based on the measurements taken under load and no load conditions, the performance parameters of motors were evaluated. The results of the analysis are summarised in table 5.1.1.1. For comparison sake, the manufacturer data of design efficiency and power factor at the operating load has been included in the table. It should be noted here that these values are based on the average performance characteristics for the standard motors as claimed by manufacturers. They are however only indicative of their performance and would vary depending upon the type of specific design and the manufacturer.

Table 5.1.1.1 Comparison of operating and design efficiency

	Rated		Measured		Designed	
Application	KW	A	Loading	Efficiency	Loading	efficiency
PP3*	45	78	85.35	87.29	75	93
HMT-1*	90	147	8.20	67.1	75	94.5
ETP Pump	15	27	71.05	81.98	50	88
New Paint shop Blower	37	65	35.76	88.22	50	89.5
Soft water pump	22	37	69.50	85.9	50	89
PP6*	45	78	88.16	90.16	75	93
PP7*	11	20	62.35	85.73	50	86

Based on the evaluation of performance parameters of the motors tested, the possibilities of replacing old and inefficient motors were studied. It was found that in spite of wide differences in efficiency levels in the presses reduction of input energy should not be substantial to justify replacement because of the fluctuating nature of the operating load. The only case where replacements were techno-economically attractive was the ETP pump. Which is illustrated below.

The following case study for ETP pump illustrates the savings that could be achieved by replacing an old inefficient motor with a new and efficient motor.

5.2 Case study

The objective of the study is to examine feasibility of using a new motor in place of old inefficient ETP pump motor no-2 and work out the associated energy savings. The motor is presently being driven by 15 kW, 27 amps, squirrel cage induction motor and its loading was measured as 71.05 percent.

A Existing motor details

Rating	15 kW
Full load current	27A
Full load speed	1450 rpm
Full load efficiency	90%

B Existing operation

Input power	13.3 kW
Efficiency	81.98%
Percentage loading	71.05%
Load at shaft	10.9 kW

C Proposed new motor

Rating	15 kW
Full load current	27A
Full load speed	1450 rpm
Power loading (for the same load)	71.05%
Efficiency (at the operating load)	88%

D Energy savings with new motor

Reduction in input power	0.9 kW
Annual saving in energy charges	Rs 22109
Estimated net investment in replacement	Rs 35000
Simple payback period	1.5 years

6

Compressed Air Systems

6.1 Introduction

There are five numbers of air compressors operating in the Maruti car component manufacturing plant. Two are of screw type, two reciprocating type and fifth compressor's type not mentioned. All the compressors are of lubricating and water/ air-cooled type. One screw compressor runs at a time and other is stand by. Reciprocating compressors are presently not in use.

The compressed air is generated, conditioned (removal of oil, moisture and dirt) and supplied for various purposes for a number of pneumatic operations and controls in the various processing equipment through one common header. Three receivers are storing the compressed air, supplying it to one common header through three separate pipelines. The vertical type air receiver provided for two individual reciprocating compressors and for the combination of two screw compressors. Air receiver with screw compressors is fitted with automatically operated drain valve to facilitate the water drainage. The compressors are designed for the rated pressure of 7.0 kg/ cm^2 (g). The average level of operating pressure at the receiver is 6.5 kg/ cm^2 (g). The compressors were switched-on and off automatically as the lower and upper pressure limits are achieved. From the receiver, air is supplied to the header and further to number of equipment (indigenous and imported) for different purpose. The air dryer is installed after the individual receiver under two sheds for four (4) compressors. The maximum and minimum designed (gauge) pressure of compressed air required at the end use equipment is 5.5 kg/ cm^2 (g) and 3.0 kg/ cm^2 (g) respectively. The list of system/ equipment is mentioned in the table 6.1a.

Table 6.1a System/ equipment using compressed air

Sl. no	System/ equipment	Designed pressure (kg/ cm^2, gauge)
1	Electro-pneumatic press	5.5
2	Spot seam welders	4.5
3	Pneumatic tools	4.5
4	Oil burners with 3 way valve	3.0
5	Paint shop with 3 way valve	3.0

The detail of four compressors is given in table 6.1b. The details of compressor #1 are not available.

Table 6.1b Detail of air compressors

No.	Model	Motor (kW)	Rated pressure (kg/cm², g)	FAD (cfm)	(m³/min)
Reciprocating type compressors					
2	EH 200M	37.5	7.0	200	5.66
3	EH 200M	37.5	7.0	200	5.66
Screw type compressors					
4	GA 1107 (W)	110	7.0	600	16.98
5	GA 1107 (W)	110	7.0	600	16.98

6.2 Free air delivery (FAD) test

Compressors are designed to deliver the fix quantity of air at certain pressure. But, due to ageing, wear and tear or poor maintenance compressor may not deliver the specified quantity of air. By performing this test, actual output of a compressor can be assessed. Performance of two screw compressors and two reciprocating compressors is given in table 6.2 below.

Table 6.2 Operating parameter of the receivers and four compressors

Sl. No	Parameter	#2	#3	#4	#5
1	Capacity of the receiver (m³)	0.13	0.13	2.72	2.72
2	Capacity of the interconnecting pipes & separator* tank (m³)	0.7978	0.7978	2.4122	2.4122
3	Initial pressure (bar abs.)	2.19	1.013	1.013	1.013
4	Final pressure (bar abs.)	6.08	6.688	7.355	7.355
5	Pump-up time (minutes)	1.07	1.03	1.9679	1.8679
6	Actual FAD (m³/min)	2.97	4.50	16.33	16.93
7	Design FAD (m³/min)	5.66	5.66	16.98	16.98
8	Average of actual load on motor (kW)	28.05	28.05	68.38	68.38
9	Sp. power consumption (kW/m³/min)	9.44	6.23	4.19	4.04

- The in-built separator tank is installed adjacent to the compressor cylinder.

The specific power consumption (kW/m³/min) of the compressors is calculated. It is the actual shaft power to generate one m³/min of compressed air, when the compressor is running at full load.

$$\text{Specific power consumption (kW/m}^3\text{/min)} = \frac{\text{Actual electrical power input}}{\text{FAD (m}^3\text{/min)}}$$

If the actual free air delivery, by the above test, comes below 80%, of the rated or designed capacity, the compressor needs overhauling. It is clear from the table that actual FADs of compressor#1, #2, #3 and #4 are 52.5%, 79.5%, 96.2% and 99.7% respectively. The FAD for compressor #4, #5 are okay where as the same of compressor#2, #3 is below the satisfactory level. Because of this specific power consumption for compressor #2, #3 are quite high compared to compressor #4, #5. It is therefore recommended to get compressor#2 and #3 overhauled immediately to have the better productivity and lower energy consumption.

6.3 Compressed air leakages

Compressed air leakage forms a major source of energy wastage. During the energy audit study, considerable leakage was noticed from pipe joints, valves, pneumatic tools, etc. It is strongly recommended to identify the leakage points and arrest the same. Though, it is not possible to make compressed air system 100% leak proof, but air leakage above 10%, certainly, need in-depth study of the network. The leakage test, to quantify the leakages in the system was attempted three times during the lunch break because most of the machines/tools using compressed air stopped during the period except a few tools which had to work continuously, on that day. During the first and second trial within an hour time, the compressor #5 did not unload for 15 minutes in each because the major quantity compressed air goes out of the distribution system. It implied that the large quantity of compressed air is continuously lost from the distribution lines through either pneumatic tool or leakage points. Plant personnel immediately attended for detection, shutting off selective pneumatic tools and proper utilisation of compressed air in the entire distribution line after the first/ second trial. They required immediate shutting off the tools necessitating the start of unloading operation of compressor #5 at the maximum level pressure setting. The maximum unloading time of compressor #5 was required by observing the pneumatic tools at shut off condition immediately, and maintain the lunch break without compressed air consumption. Practically, the unloading time of compressor #5 was increased significantly after shutting off large number of tools and expected it not to fall further at close condition of tools. However, the operation of few tools could not be avoided because of either backlog production or carelessness/ mistake of operator within the lunch period. The loading, unloading time in third trial was 0.72 minutes, 1.65 minutes to generate adequate compressed air volume and to meet the same production target. Plant personnel reported during the draft report presentation about the large number leakage points plugging and the possibility of getting reduced loading & unloading time of both the screw compressors. They carried out the in-house trial for the improvement in loading & unloading time and overall leakage in distribution system within next 10 days. The loading, unloading time is appreciably reduced to 0.416 minutes & 0.5 minutes. The unloading time is 20% more than the loading time, which is marginal. Almost same rate of discharge and generation of compressed air in the system implies the continuous loss or unavoidable operation of few pneumatic tools. Therefore, the compressed air loss is further increased proportionately.

The leakage in the compressed air system can be quantified by running the compressor with all air using equipment shut off. The leakage test in three trials was carried out with the compressor #5. The leakage rate in the compressed air line was calculated to be about 30.4%. The significant leakages in the system might be due to a few tools like sweeping and pneumatic gun, which are working during the measurement in third trial. It was suggested to stop the sweeping and pneumatic gun during the lunch/ tea break and not to allow any leakage point in future. Plant personnel reported about the continuous in-house observation for further detection of leakage through any point in next 7 days. They target for the leakage rate and hourly basis monetary saving at lower side after in-house assessment (before fourth trial) in the compressed air line. They carried out in-house fourth trial with a few sets of reading. The operating compressor and pressure was assumed to be the same as third trial because these are not mentioned for the in-house test report. Even leaving a margin of 10% leakage for untraceable points in the compressed air line, the reduction in electricity consumption was achievable in the plant, with plugging out the leakage would be handsome amount annually. The annual electrical energy saving was estimated to be 70200 kWh as per the third trial, and the corresponding monetary saving would be Rs. 2.94 lacs. The average monetary saving rate was estimated to be Rs 59/- per hour.

The leakage rate in the fourth in-house trial is calculated to be 45.4%. The revised estimate of the higher leakage rate may be due to some unavoidable utilisation of compressed air at any point in the distribution system. The annual electrical energy saving work out to be 1,21,970 kWh, and the corresponding monetary saving would be Rs. 5.11 lacs. The average monetary saving rate would be Rs 101/- per hour. .The details of third and fourth trial are given in annexure 6.1 (a) and annexure 6.1 (b) respectively.

The literature on the method of the overall leakage is given in Annexure 6.2 (a) and the leakage testing method in annexure 6.2(b). Source of the document is as under:

Annexure 6.2(a): Fuel Efficiency Booklet. Energy Efficiency Office, Deptt of Energy, Millbank, London, UK.

Annexure 6.2(b): Talbot E M. Compressed Air Systems. Fairmont Press Inc., Atlanta, Georgia 30324.

6.3.1 *Minimising compressed air leakage*

It is difficult to detect air leakage as they cannot be seen and smelt. While large leakages are easily detected by hissing sound generated, it is difficult to detect small leakages, which can only be detected by applying soap solution. Some of the most susceptible points are:

a) threaded pipe joints
b) flange connections
c) valve stems
d) traps and drains
e) filters
f) hoses
g) connectors
h) operating valves on pneumatic devices
i) check valves
j) relief valves
k) end use machines or tools
l) mist (oil) eliminators

The air loss due to leakage can be quite significant depending on the air pressure. Table 6.3.1 gives the leakage through various orifice size and energy wastage at 7 kg/cm^2 (g) and 5 kg/cm^2 (g) air pressure.

Table 6.3.1 Power wastage at different pressures

Orifice dia.	Air leakage (scfm)	Power wasted (kW)
At 7 kg/cm^2 (g) pressure		
1/16" (2 mm)	6.49	1.26
1/8" (3 mm)	26	5.04
1/4" (7 mm)	104	20.19
1/2" (13 mm)	390	75.47
At 5 kg/cm^2 (g) pressure		
1/16" (2 mm)	3.92	0.71
1/8" (3 mm)	8.8	1.60
1/4" (7 mm)	60.5	10.98
1/2" (13 mm)	133.1	24.16

(m^3/min = 39.2 scfm)

It is recommended to get the entire compressed air distribution system tested with soap solution once in every six months.

6.4 Calibration of automatic on-off system, pressure gauges on compressor & receiver

The automatic on/off switch of the compressor #2, #3 and #4, #5 operate at pressure 5.8/ 6.4 kg/cm^2 (g) and 6.0/ 6.5 kg/cm^2 (g) respectively. Measurements were carried out after the leakage plug at the selective points. The pressure gauge reading on the receiver is always higher than the pressure gauge reading on the compressor #5. Therefore, it is recommended to calibrate periodically the pressure gauges/switches fitted with the compressors and receivers. It is also recommended to calibrate periodically the automatic system so that the differential pressure setting for the compressor on-off operation does not go beyond 0.5 kg/cm^2 (g).

6.5 Use of automatic drain valve in air receiver

It was observed that the drain valve fitted with common air receiver of two screw compressors was automatically operated to facilitate the water drainage. The duration of water drainage is one minute at the regular interval of 4 minutes. The manual operation of receiver's drain valve fitted with two individual reciprocating compressors and two screw compressors were reported to be regular and occasional (when bypassing the automatic system). The water drainage through the drain valve fitted with individual air receiver of two reciprocating compressors was not done during the visit. The frequency of manual drainage of moisture from the receivers is twice a day during the shutdown of screw compressors. The manual drainage provision not only passes the water but also allow the compressed air to pass to the atmosphere intermittently. By using the automatic drain valve regularly/ continuously, water would only be allowed to pass accordingly (intermittently in nature), thereby, reducing the wastage of compressed air.

6.6 Inlet air temperature

The temperature of air at the inlet of the compressor is very important, as rise in temperature will increase the energy consumption because of increased volume of air. Thus, lesser the temperature of air at compressor inlet, lesser would be the energy consumption of compressor. The effect of inlet air temperature on compressor performance is given in table 6.6.

The individual air filter at the suction end was located very close to the compressor #2, #3 and adjacent to the compressor #4, #5. Temperature of air in the ambient and compressor shed was measured using thermocouple and it was found that the temperature of the inlet air to the compressors was close to the ambient temperature. However, care should be taken against any possible change in temperatures.

Table 6.6 Effect of inlet air temperature on compressor performance

S.No	Temperature of intake air (°C)	Volume required to deliver 1000 m^3 at 21°C (m)	Percentage saving/loss related to 21°C
1	5	943	5.7
2	10	982	3.8
3	16	981	1.9
4	21	1000	0
5	27	1020	-1.9
6	32	1040	-3.8
7	37	1060	-5.7
8	43	1080	-7.6
9	49	1100	-9.5

Note: The negative sign in the table indicates energy loss.

7 Cooling Towers

The plant is equipped with two cooling towers to meet the cooling water requirements of Compressors, Press shop and 100 spot welders in Weld shop. The cooling towers are of single cell round bottle shaped counter-flow induced draft type and fitted with fibre reinforced plastic (FRP) fan blades. The fan of 1330 mm diameter is fitted with the 5 HP motor. The cooling towers are fitted with identical PVC fills vertically placed through which water falls in to the sump. M/s Advance Reinforced Plastics Pvt. Ltd. installed 60 HP motor with the individual pump of the cooling tower. These cooling tower pumps are operating well after retrofitting work done in-house. The marginal reduction in diameter of individual impeller of the pumps is done as retrofitting, which allows individual impeller to operate by 30 HP motor to obtain the desired head. The cold water gets collected in an underground tank before it is distributed to all the areas. Normally, two towers individually operate for 20 hours daily. The annual operating hours of each cooling tower is 5510 hours. The detail of the cooling tower is given in the Table 7.0.

Table 7.0 Design detail of two identical cooling towers (CT)

Parameter	Cooling tower
Make	Advance Reinforced Plastics Pvt. Ltd.
Year of installation	1986
Pump motor rating (kW)	22
Inlet water temperature* (OC)	N.A.
Outlet water temperature* (OC)	N.A.

*Design level

7.1 Performance Evaluation

The temperature measurement of water streams was carried out and attempt was made to estimate the cooling tower performance when the most of equipments/ machines were operating on normal load condition. The designed cooling capacity of the both towers is same. The parameters measured were temperature of incoming and out going cooling water, ambient dry and wet bulb temperature, total dissolved solids, pH of water at cooling towers sink, etc.

The range (difference in cooling tower inlet and outlet water temperature) and approach (difference in cooling tower water outlet and ambient air wet bulb temperature) for these cooling towers are given in Table 7.1 along with the measured parameters. The temperature of cold water in the sump, before falling in the underground tank is measured to be 23.7°C. Range and approach are two main factors governing the performance of a cooling tower. For optimum performance, range should be as high as possible and approach should be as low as possible.

Table 7.1 Operating parameters (identical for two cooling towers)

Parameters	Cooling Tower
Average in-coming water temperature to cooling tower (°C)	24.0
Average out-going water temperature from cooling tower (°C)	23.7
Dry bulb (ambient) temperature (°C)	28.1
Wet bulb (ambient) temperature (°C)	20.7
Range (°C)	0.3
Approach (°C)	3.0

The average temperature of incoming and outgoing water of two cooling towers is almost same. The make-up water (at ambient temperature) is also mixed with the warm (incoming) water in both the cooling towers. Due to the underground storage system, the average temperature of cold water in the tank further reduces slightly. The fan is continuously operating for regular circulation of air through the falling spray of water. However, the outgoing water temperature in cooling towers is slightly lower than the incoming water temperature and, therefore, has the lower range. The approach is also higher in cooling towers. The range is lower because of inadequate cooling of incoming water to the tower, without appreciable effect on falling water through the fills. The effect of fans operation in cooling water is minor.

7.2 Water spray and fills

The fills in a cooling tower facilitate heat and mass transfer between the circulating water and the air. Both the cooling towers in the plant are having PVC fills, which were not performing properly. The performance of cooling tower depends on the operation and condition of its water spray/ distribution system also. The water entering the tower is to be evenly distributed as it enters the fills. Ideally, the cooling tower requires proper balancing of the water spray/ distribution pipes and proper operation of the distribution holes. It is recommended to replace the selective clogged/ jammed section of fills, which provides maximum water exposed surface area to air for better heat transfer.

7.3 Cooling tower fan

The average temperature of outgoing water from the cooling towers and WBT is 23.7°C and 20.7°C respectively. The designed setting of water temperature at inlet/ outlet of the cooling towers is not available. It is suggested to switch off the cooling tower fan manually for additional 25 days when the ambient temperature falls below the 25°C (during the evening and night of October and February). The savings in the individual cooling tower because of this will be 676 kWh or Rs.3,000 per annum.

8 Solar Thermal Energy

Solar Thermal systems use heat energy form solar radiation to heat suitable media like water, air or Thermic fluid.

Several solar thermal technologies have been developed. These includes solar flat plate collector based water heating systems, solar air heaters, solar dryers, solar concentrating cookers, solar box cookers, steam generation system etc.

Solar water heaters based on flat plate collector technology and evacuated tubular collector technology are now commercialised and standardised products available in the market. Solar flat plate collectors are now approved by ISI (Indian standards Institute) and only ISI approved collectors are eligible for the concessional loan scheme of IREDA.

8.1 Solar water heating systems

8.1.1 Technology overview

The solar water heating system (SWHS) using a flat plate collector is one technology, which is technically and commercially mature. There are two distinct markets for solar water heating systems in India (i) domestic and (ii) commercial and industrial. In the commercial sector SWHS are used to meet the hot water demand e.g. in hotels, hospitals etc while in the industrial sector these systems are used for preheating boiler feed water or to meet process heating requirements. In the domestic sector SWHS's are used to meet the hot water demand. These systems are commonly employed in European countries for meeting the space-heating demands.

Commercially available solar water heating systems basically consist of flat plate solar collectors and an insulated water storage tank. The flat plate collector is a selectively coated metal plate called an absorber. The absorber has a very high absorbance for electromagnetic waves in the range of 0.2 to 2.0 micrometer and the major component of solar radiation falls in this range. Further, the absorber has low emittance in the near infrared and infrared region. Metal oxides are generally used as the selective coating. Thus, the absorber absorbs solar radiation and converts it into thermal energy, which is transferred to the water flowing in the riser tubes in the absorber. The risers are connected to a common header in the collector. The absorber plate is insulated on the backside and the front side is covered with glass to reduce heat loss. For optimum exposure to the solar radiation the collectors are placed facing south with an inclination equal to the latitude of the place + 15 degrees. The smaller capacity systems (<2000 litres per day) normally operate on the thermosiphon principle, in which the water in the risers rises on account of a reduction in density on heating. The hot water thus generated is then stored in an insulated storage tank. However, for larger capacity systems, a pump with necessary controls is required for the circulation of water and such systems are designated forced flow systems. Solar thermal systems used in the domestic sector are of a smaller capacity, normally below 1000 litres per day.

The use of solar water heating systems results in direct local and global environmental benefits. The domestic solar water heating system can potentially save 0.6–0.9 tonne of CO_2/m^2/annum based on electrical savings, depending upon the resource mix. In the case of commercial and industrial systems emission reductions are in the range of 0.2–0.4 tonne of CO_2/m^2/annum as they mainly replace the boiler fuel. These systems have a very significant emission reduction potential, and thus high market potential for selling carbon credits.

8.2 Application of solar systems in the factory

During energy audit survey at the factory of Mark Auto following areas were identified for installation of solar thermal systems

8.2.1 Canteen

In an industrial canteen hot water is required for a) preparation of tea/coffee, b) preparation of rice, curries etc, and c) cleaning & washing of utensils. Use of hot water for utensil cleaning is recommended since hot water is good for cleaning oily utensils and it is hygienic too.

Solar Water heating systems are effectively used for meeting this requirement by providing preheated water at up to 80° C. Different solar thermal technologies are now available for this purpose. The canteen serves meals, snacks and tea for management, staff and workers.

Total number of persons served is around 600 Nos. The requirement of meals is for 600 persons. And requirement of hot water for tea /coffee making is for 1400 cups, approximately 250liters.

8.2.2 Present system

Currently water is boiled on gas stoves. Electric geyser is occasionally used for water heating. LPG and electricity are both costliest fuel when different fuels are compared on Rs. /energy delivered basis. The existing system is not only inefficient but also unsafe as hot water is carried in open utensils.

8.2.3 Proposed solar system

Flat plate collector based solar water heating system of 3500 lit per day capacity is recommended for the canteen application.

8.2.4 Detailed energy calculation and pay back period for solar system in canteen

8.2.4.1 Solar system design calculations

1	Client	M/s Mark Auto Industries Ltd, Gurgaon
2	Application	Hot Water for Canteen
3	Location	Gurgaon, Haryana
4	Assumptions	

Requirement of hot water	3500 Lit per day
Average hot water temp required (t2)	75 Deg C
Average inlet cold water temp. (t1)	20 Deg C
Solar radiation level	4.5 kWh per day
Solar system efficiency	45%
No. of working days per year	300
Conventional system efficiency	75.00%
Conventional fuel used	LPG
Calorific value of fuel used	47460 KJ/m^3
Cost of fuel	30.00 Rs. per kg.
Income tax rate	38.00%
Depreciation in first year	80.00%

5	Energy calculations	
	Energy required for hot water generation	M X Sp.HEAT X (T2-TI) KJ per day
		= 808500 KJ per day
6	Solar system area required	= 110.90 sq.m.
	Hence 55 collectors, each of 2 sq.m area, are required.	
7	Budgetary cost of solar system	Rs. 84000
8	Fuel saving	
	Conventional fuel required for water heating	22.7 kg/day
	Fuel saved per day	22.7 kg/day
9	Cost of fuel saved per day	Rs. 681 per day
10	Annual fuel saving	Rs. 204425.00 per year
11	Depreciation benefit	Rs.255360.00
12	Net investment on solar system	Rs.584640.00
13	Simple payback period	2.85 Years
14	Note	

1. The simple payback period is based on minimum output from solar system. However actual output may be more.
2. Soft loan scheme advantage will reduce the initial investment
3. Solar system cost may vary depending on supplier and type of technology

8.2.4.2 Solar system for shop floor applications

Medium temperature solar thermal heating system for Thermic fluid heating, which will take care of dip coating line and other requirements, is considered. The Solar system calculations for THERMOPAC-I are given below.

Solar system design calculations for thermic fluid heating

1	Client	M/s Mark Auto Industries Ltd, Gurgaon
2	Application	Thermic fluid heating
3	Location	Gurgaon, Haryana

A	Fuel and thermic fluid details	
1	Fuel used	L.D.O.
2	Calorific value of fuel	10,700 Kcal/kg
3	Density Of fuel	860 Kg/Cu.m
4	Thermic fluid used	Therminoll
5	Thermic fluid density	884.60 Kg/cu. M
6	Thermic fluid sp. Heat	0.44 Kcal/kg °c
7	Fuel cost	Rs.18.6 /Kg

B	Thermopac I		
	Thermic fluid heater efficiency	74.75%	
	Actual fuel consumption	56.00 Lit /hr	
	Operating hours	11 hr/day	
	Thermic fluid return temp	220	°C
	Thermic fluid outlet temp.	290	°C
	Heat energy generated by thermopac		
	Heat gen =	427469.28	Kcal/Hr
	Thermic fluid flow rate	15689.43	Lit/Hr

Solar system area required for meeting 6hr/day requirement by solar thermic fluid heater

Solar radiation level	4.5 Kwh/day/sq.m.
Solar system efficiency	50%
Solar system area required	2200m^2
Solar system cost	Rs 2.3 crore

Note:

1. Solar dish or parabolic trough collectors can only be used
2. These collectors are available in international market and economic feasibility will depend on actual costs quoted by supplier.

List of solar system manufacturers and MNES scheme details are enclosed in Annexure 8.1.

8.3 Solar system for washing machine

8.3.1 Requirement for Washing machine

Component washing machine uses hot water at 55-60 °C for cleaning the components. The water is stored in a tank of 700lit capacity and it is heated using electrical heaters. Hot water at 55-60 °C temperature is sprayed on components, which are mounted on conveyor.

Average daily consumption of electricity is 700kWh.

The machine operates in three shifts and water in the tank is changed in every shift. Besides this around 100lit of fresh water is required per shift as make up water.

8.3.2 Solar system to meet complete energy requirement for heating water

Based on above following is the requirement of solar system

Total energy requirement
- 700kWh per day = 700X3600 kJ per day = 2520000 kJ per day

Assuming average 4.5 kWh/m^2 per day of solar energy and average efficiency of 45% the solar system size required to meet complete demand is 350m^2 collector area. Terrace area required will be approximately, 1200 m^2.

Specially designed system using advanced evacuated tubular collectors which can heat water up to 90° C with plate heat exchanger for re-circulation of hot water will be required for this application.

The project cost will be in the range of Rs. 30,00,000/- (Rupees thirty lakhs only) and annual savings in electricity considering 300 days of full capacity functioning and unit rate of Rs. 5.00 per unit will be 700X300X5= Rs.10,50,000/- (Rupees ten lakhs fifty thousand only)
Thus pay back period will be three years based on simple payback calculation method.

8.3.3 Solar system for makeup water and fresh water requirement

Second alternative is to use solar water heating system to meet only the fresh water and make up water requirement. This requirement per day is 700X3 + 100X1 = 2200 lit. for three shift operation.

- Standard solar water heating system based on flat plate collector technology can be used for this application.
- System capacity will be 3000 lit per day.
- Solar system of 30 solar flat plate collectors each having 2 m^2 area will be required.
- Total ground area required for installation of system will be 120m^2.
- The system cost will be Rs. 2,25,000/--.
- The system will save @100 units of electricity per day.
- Annual saving will be @ 30000 units. The annual saving at @ Rs. 5.00 per unit will be 30000X 5 = Rs.1,50,000/- .
- Simple pay back period will be @2 years.
- Savings in electricity will be around 14% of total energy required for water heating.

Thermal efficiency calculation of thermopacs

	Thermopacs	
	#1	#2
Average LDO consumption (lit./hr)	56.4	54.1
Specific gravity LDO	0.86	0.86
Average LDO consumption (kg/hr)	48.5	46.5
GCV of LDO (Kcal/kg)	10200	10200
Moisture in fuel (wt %)	0.3	0.3
H_2 in fuel (wt %)	12	12
O_2 in flue gas (%)	10.3	9.3
% excess air	96	79
Theo. Air requirement (kg/kg of fuel)	14.1	14.1
Total quantity of air (kg/kg of fuel)	27.7	25.3
Maximum CO_2 (%)	15.8	15.8
CO_2 in flue gas (%)	8.1	8.8
Flue gas temperature (°C)	248	189
Ambient temperature (°C)	30	30
Moisture in air at 75% RH &31°C (kg/kg of air)	0.025	0.025
Cost of LDO (Rs/lit)	16	16
Dry flue gas loss	15.32	10.25
Loss due to H_2 & moist. in fuel	7.23	6.93
Loss due to moisture in air	0.71	0.47
Structural loss	0.93	0.93
Total Loss	25.25	19.65
Thermal efficiency of Thermopac	75.81	81.41

Annexure 1.1 (contd....)

Formulae

Basic Data	**Thermopack**
Average LDO consumption (lit./hr)	56.4
Specific gravity LDO	0.86
Average LDO consumption (kg/hr)	48.5
GCV of LDO (Kcal/kg)	10200
Moisture in fuel(wt %)	0.3
H2 in fuel(wt %)	12
O2 in flue gas (%)	10.3
Theoretical .air requirement (kg/kg of fuel)	14.1
Flue gas temperature (oC)	248
Ambient temperature (oC)	30
Moisture in air at 75% RH &31oC (kg/kg of air)	0.025

Calculations

1) Excess air (%)

$$= \frac{O_2 \text{ in flue gas X } 100}{(21 - O_2 \text{ in flue gas})} = 10.3/(21-10.3)$$

= 96%

2) Total quantity of air (kg/kg of fuel)

= (1+%Excess air/100) X Theoretical air requirement
= (1+96/100) X 14.1
= 27.7 Kg

Losses

1) Dry flue gas loss (%)

= Flue gas quantity per kg of fuel X Specific heat of flue gas X (Flue gas temp. – ambient temp.) X 100/ GCV of fuel in kCal/kg

Flue gas quantity per kg of fuel = (Total quantity of air per kg of fuel + 1)
= (27.7 + 1) = 28.8 kg

Specific heat of flue gas = 0.25 kCal/kg-°K

Dry flue gas loss = 28.8 X 0.25 X (248-30) X 100/10200
= 15.32%

2) *Loss due to hydrogen and moisture*

= (Moisture in fuel (wt%) + 9 X H_2 in fuel(wt%)) X (0.48 X (Flue gas temperature - 100) + 540+ (100 – Ambient temperature))/ GCV of fuel in kCal/kg

= (0.3+9X12) X (0.48 X (248-100) + 540 + (100-30))/ 10200

= 7.23%

3) *Loss due to moisture in air*

= (Moisture in air X Total air quantity per kg of fuel) X (0.48 X (Flue gas temperature – Ambient temperature)) X 100/ GCV of fuel in kCal/kg

= 0.025 X 27.7 X (0.48(248-30) X 100/10200

= 0.71%

4) *Structural Losses*

= Heat transfer coefficient X Surface area X (Average surface temperature – Ambient temperature) X 100/ (fuel consumption per hour X GCV of fuel)

Heat transfer coefficient =

4.876x10^{-8} X Emissivity X ((Av. Surface temperature + $273.15)^4$ – (Ambient temperature + $273.15)^4$)/ (Av. Surface temperature – Ambient temperature) + 1.683 X (Av. Surface temperature – Ambient temperature)$^{0.25}$ X (2.857 X Air velocity + $1)^{0.5}$

= 4.876x10^{-8} X 0.6 X ((58 + $273.15)^4$ – (30 + $273.15)^4$)/ (58 – 30) + 1.683 X (58 – 30)$^{0.25}$ X (2.857 X 1 + $1)^{0.5}$

= 11.34 kcal/m^2-hr-°C

Emissivity = 0.6
Average surface temperature = 58°C
Air velocity = 1m/sec.
Surface area = 14.59 M^2 (dia. = 5' and height = 10')

Structural loss = 11.34 X 14.59 X (58-30) X 100/(48.5 X 10200)

= 0.93%

Annexure 1.2

Saving in dry flue gas loss due to optimisation of excess air in thermopacs

	Thermopac#1	*Thermopac#2*
Existing excess air level (%)	96	79
Existing dry flue gas loss* (%)	16.03	10.72
Reduced excess air level (%)	30	30
Reduced dry flue gas loss* (%)	10.89	7.95
Saving in loss (%)	5.14	2.77
Existing efficiency (%)	75.81	81.41
Improved efficiency (%)	80.94	84.19
Existing LDO consumption (lit/hr)	56.4	54.1
Reduced LDO consumption (lit/hr)	56.4X(75.81/80.94)	54.1X(81.41/84.19)
	52.8	52.3
Saving of LDO (lit/hr)	3.6	1.8
Saving of LDO per annum (lit/yr) (@11 hrs. & 9 hrs. a day for Th.#1 and Th.#2 respectively and 300 days/year)	11812	4815
Monetary savings per annum (@Rs 16/lit of LDO)	Rs. 1.89 lakh	Rs. 0.77 lakh

* includes loss due to moisture in air

Annexure 1.3

Savings due to installation of heat recovery unit

	Thermopac#1
Existing flue gas temperature (°C)	248
Reduced flue gas temperature after installation of HRU (°C)	160
Available temperature difference (°C)	88
Specific heat of flue gas (kCal/kg- °C)	0.25
Flue gas quantity (kg/hr)	879
Total heat availability (kCal/hr)	19344
Effectiveness of the HRU	0.45
Actual heat gain by water (kcal/hr)	8705
Corresponding fuel saving (lit/hr) (considering the improved efficiency 80.94%, GCV of LDO=10200 kcal/kg)	1.22 = (8705/(10200 *0.86*0.8094))
Fuel savings per annum (lits.) (@11 hrs. a day and 300 days/year)	4042
Monetary savings per annum (@Rs 16/lit of LDO)	Rs. 0.65 lakh
Estimated investment	Rs. 1.1 lakh
Simple payback period	About 20 months
Quantity of water that can be heated from 30°C to 60°C (kg/hr)	290

Annexure 1.3 (contd...)

Through Courier

THROUGH COURIER

SER: JP:
December 20, 2002

Research Associate
Industrial Energy
TERI,Habitat Place, Lodi Road
New Delhi-110003

Kind Attn: Shashank Jain

Sub: Requirement of water pre heater for Thermopac TP-06

Dear Sirs,
We are in receipt of your enquiry thr.e-mail on the captioned subject. As desired by you, we are submitting our **special offer** as follows for your kind perusal and necessary action.

#Heat exchanger assembly	85650 00
# Set of Instruments (2 no.TI, 3 nos.Limit switches, 2 nos.valves)	21500.00

TECHNICAL SPECIFICATIONS:

Sr No.	Description	
I	Heating surface area	3.6 m^2
II	Material of construction	SS
A	Tubes	SS
b	Water jacket	IS:2062
c	Bottom+top tube sheet	SS
d	Flue gas inlet duct	IS:2062
e	Flue gas out duct	IS:2062 with FRP lining
III	Maximium flue gas flow rate	996 kg/hr
IV	Temperature profile	
a	Average flue gas I/L temp	248+/- 10°C
b	Average flue gas O/L temp	180+/- 5°C
c	Water I/L temperature to WPH tank	25°C
d	Water O/L temperature from WPH tank (To FW pump)	75+/- 5°C
e	Maximumu water flow rate (FW pump)	400 kg/hr
f	Pressure drop flue gas side	35mmwc

We hope you will find the above in the line with your requirement.

Thanking you, and looking forward to receive your valued order.

Yours faithfully,

For **Thermax Limited,**

J.P. SHARMA
EXECUTIVE
Encl : Comm. Terms & Conditions
: Exclusion

COMMERCIAL TERMS AND CONDITIONS

PRICE BASIS : Prices are Ex-Works Pune.

PACKING & FORWARDING : Shall be charged extra @3%.
(NIL IN YOUR CASE)

EXCISE DUTY : Shall be charged extra/as applicable at the time of dispatch.

SALES TAX : Shall be charged extra @4% against Form-C or else full Tax will be charged extra.

FREIGHT,OCTROI,INSURANCE}
OR ANY OTHER GOVT. LEVIES) : Shall be arranged and borne by you.

PAYMENT TERMS : 50%Advance alongwith order and balance against proforma invoice, prior to dispatch.

DELIVERY : 12-14 Weeks from the date of receipt of your
confirmed der alongwith requisite advance.

VALIDITY : 30 Days from the date of this offer.

AUTHORISED SIGNATORY

Exclusions: -
- Any ducting and piping to and from WPH.
- Supporting structure.
- Water storage tank.
- Riser / Downcomers.
- Any thing not specifically mentioned in above offer.

Annexure 2.1

Heat balance of electric oven#2

Average production for 7 days (16-23 Oct.'02) in kg/day = 3845
Average electricity consumption per day for the same period = 288
Nos. of batches per day = 13
Nos. of operating hours per day = 7
Density of air (Kg/m^3) = 1.15
Final component temperature (°C) = 180
Ambient temperature (°C) = 25
Average specific heat of steal (kcal/kg-°C) = 0.1
Average specific heat of air (kcal/kg-°C) = 0.25
Assumed flow of circulation fan (m3/sec.) = 0.97
Assumed quantity of air vented in m3/hr. (@ 5% of circulated air) = 175
Dimension of oven (l x b x h) = 3x3x3
Surface area of oven (m^2) = 5x3x3 = 45
Average surface temperature (°C) = 54
Emissivity of oven surface = 0.6
Air velocity around oven (M/s) = 1
Heat transfer coefficient (kcal/hr-m2-oC = 10.96
Assumed weight of trolley and hanger (kg) = 100

Heat required to heat the components (%) = 3845X0.1X(180-25)X100/(288x 860)
= 24.20

Heat absorbed by trolley and hanger (%) = 13X100X0.1X (180-25)X100/(288X860)
= 8.18

Heat absorbed by exhaust air (%) = (175X7X1.15X0.25X(180+25)/2) X100/(288X860)
= 14.56

Surface heat losses (%) = 10.96X45X(54-25) X7X100/(288X860)
= 33.14

Unaccounted (%) = 19.91

Annexure 2.2

Replacement of electric heating by thermic fluid heating

Connected heating load to the oven (kW) = 55
Equivalent thermal heat in kcals (@860 kcal/kw) = 47300
Average operating hours a day = 7
Heat requirement per hour (kcal/hr) = 47300
Design capacity of thermopacks (kcal/hr) = 6,00,000
Current heat duty of each thermopack = ~ 65%
Available capacity (kcal/hr) = 90,000
(Assuming it will deliver maximum 80% of the design)
Average elect. consumption in the oven(kWh/day) = 288
(16th Oct. to 22nd Oct.'02)
Savings of electricity in kWh per year = 86300
(@ 300 working days per annum)
Monetary savings per annum = Rs. 4.74 lakh
(@ Rs. 5.5/kwh)
Additional fuel consumed by thermopack (kg/day) = 41.29 = (47300X7/
(on the basis of current average operating efficiency (10200*(75.81+81.41)/2))
of both the Thermopack)
Additional LDO consumption per annum (kgs/annum) = 12388
(based on 300 day's operation per year)
Additional cost per annum = Rs. 2.30 lakh
(@ Rs. 16/lit)
Net savings per annum = Rs. 2.44 lakh

Annexure 2.3

Loss due to maintaining higher bath temperatures

Heat required to raise the temperature by 1°C additionally of 1 ton of water per water tank (kcal/day) = 1000

Specific heat of water (kca/kg-oC) = 1

Heat required to raise the temperature by 1°C of 1 ton component due to passing through the overheated water (kcal/day) = 100

Specific heat of steal (kca/kg-oC) = 0.1

Heat required for make up water requirement (kcal/day) (@10% water in one tank) = 100

Heat loss to atmosphere due to opening (kcal/day) (for 12 hrs/day operation, 30°C ambient temperature, 1 m/s of wind velocity and heat transfer area of $3.5m^2$) = 564

Total heat loss per day (kcal/day) = 1764

Equivalent LDO consumption per day (lit./day) = 1764/(.80X.81X.86X10200)

= 0.31

(Assuming heat transfer efficiency to water=80%, operating efficiency of thermopack=81%, specific gravity of LDO=0.86 and GCV of LDO=10200 kcal/kg)

Loss of LDO per annum (lit.) (on the basis of 300 working day) = 93.12

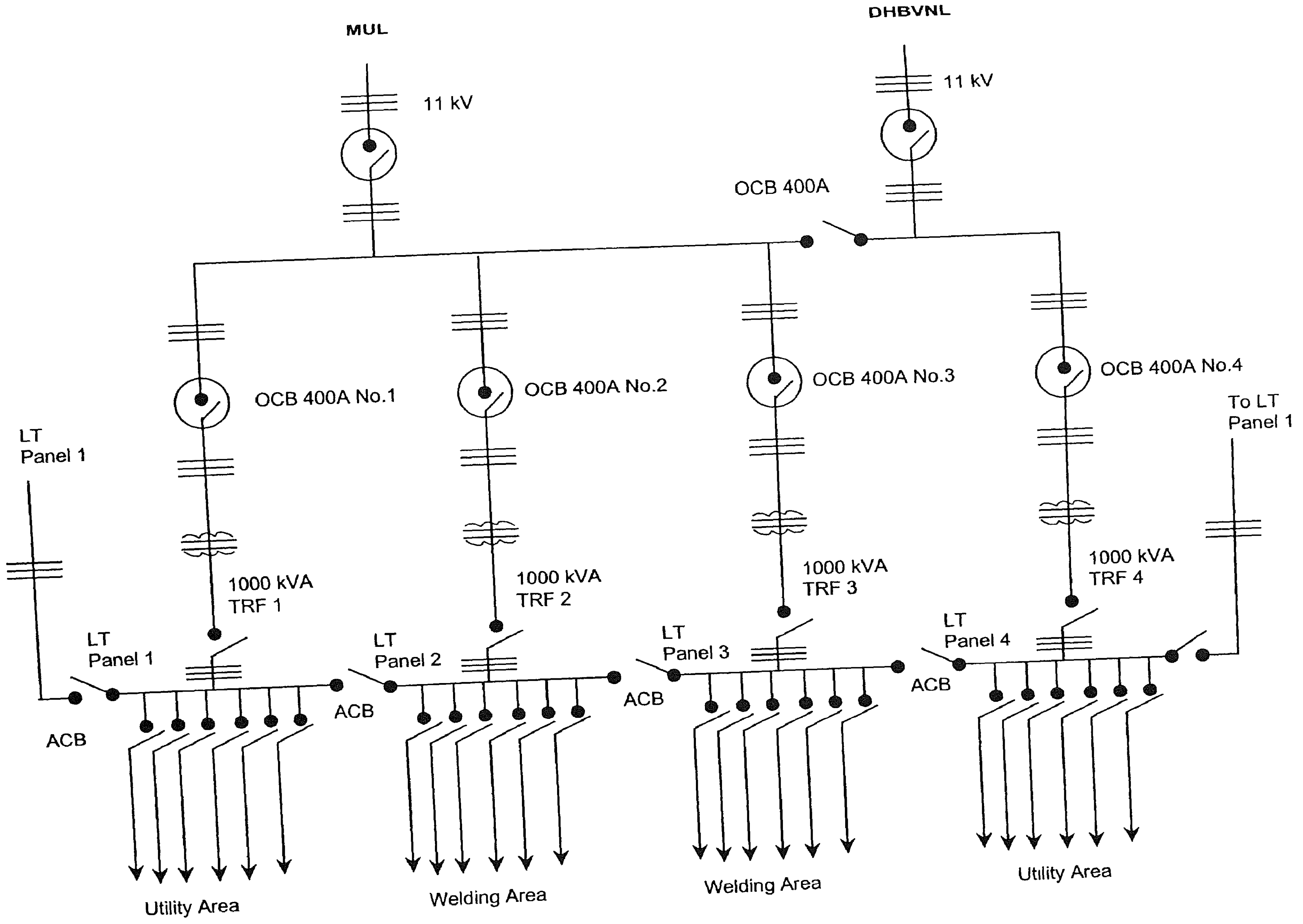
Thermal efficiency calculation of powder coating ovens

	Ovens	
	Drying	*Baking*
Average LDO consumption (lit./hr)	14.8	29.1
Specific gravity LDO	0.86	0.86
Average LDO consumption (kg/hr)	12.7	25.0
GCV of LDO (Kcal/kg)	10200	10200
Moisture in fuel(wt %)	0.3	0.3
H_2 in fuel(wt %)	12	12
O_2 in flue gas (%)	13.7	11.8
% excess air	188	128
Theo.air requirement(kg/kg of fuel)	14.1	14.1
Total quantity of air(kg/kg of fuel)	40.6	32.2
Maximum CO2 (%)	15.8	15.8
CO2 in flue gas (%)	5.5	6.9
Flue gas temperature (°C)	201	395
Ambient temperature (°C)	30	30
Moisture in air at 75% RH &31°C (kg/kg of air)	0.025	0.025
Cost of LDO (Rs/lit)	16	16
Dry flue gas loss	17.42	29.69
Loss due to H2 & moist. in fuel	6.99	7.98
Loss due to moisture in air	0.82	1.38
Structural loss	1.00	1.00
Total Loss	26.23	40.05
Thermal efficiency of Thermopac	73.77	59.95

Saving in dry flue gas loss due to optimisation of excess air in powder coating ovens

	Drying	*Baking*
Existing excess air level (%)	188	128
Existing dry flue gas loss* (%)	18.24	31.07
Reduced excess air level (%)	30	30
Reduced dry flue gas loss* (%)	8.55	18.24
Saving in loss (%)	9.69	12.83
Existing efficiency (%)	73.77	59.95
Improved efficiency (%)	83.46	72.77
Existing LDO consumption (lit/hr)	14.8	29.1
Reduced LDO consumption (lit/hr)	13.1	23.9
Saving of LDO (lit/hr)	1.7	5.1
Saving of LDO per annum (lit/yr) (@ 8 hrs. a day for and 150 days/year)	2058	6134
Monetary savings per annum (@Rs 16/lit of LDO)	Rs. 0.33 lakh	Rs. 0.99 lakh

* includes loss due to moisture in air

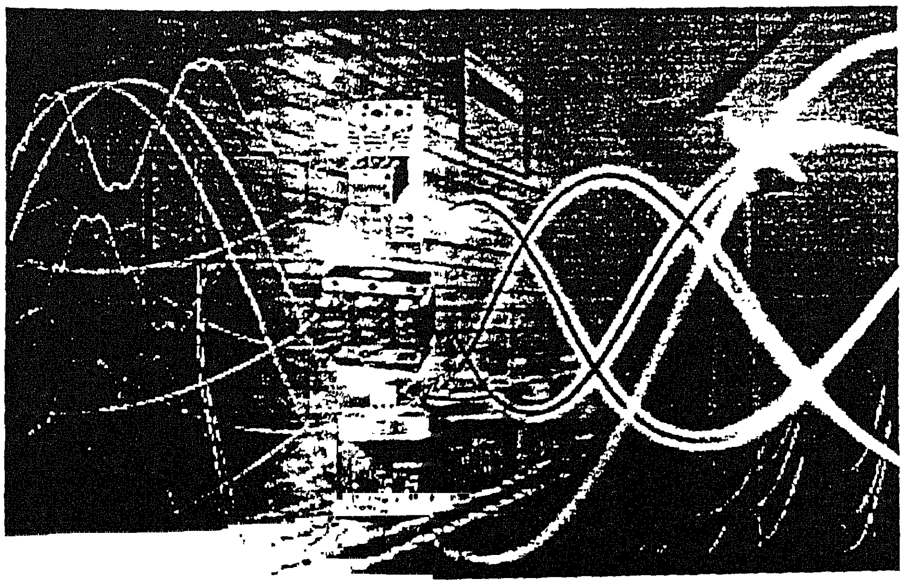

MUL
11 kV
DHBVNL
11 kV
OCB 400A
OCB 400A No.1
OCB 400A No.2
OCB 400A No.3
OCB 400A No.4
To LT Panel 1
LT Panel 1
1000 kVA TRF 1
1000 kVA TRF 2
1000 kVA TRF 3
1000 kVA TRF 4
LT Panel 1
LT Panel 2
LT Panel 3
LT Panel 4
ACB
ACB
ACB
ACB
Utility Area
Welding Area
Welding Area
Utility Area

Annexure 4.2

EPCOS

RTPFC - Real Time Power Factor Correction

Thyro - Thyristor Switch



EPCOS FK PM PFC (RM)

03.03.2002

Einfuhrung

Der Thyristor-Leistungssteller Thyro-C ist die anschlußfertige Losung fur **dynamische Blindleistungs-Kompensationsanlagen.** Aufgrund seiner Eigenschaften ergeben sich durch den Einsatz des Thyro-C anstelle klassischer Stellglieder, wie Kondensator-Luftschutzen, folgende Vorteile:

- hohe Lebensdauer durch praktisch unbegrenzte Schalthaufigkeit
- sanftes Schalten der Kondensatoren im Stromnulldurchgang
- kurze Schaltverzogerung
- geeignet zum Aufbau von dynamischen Echtzeitkompensationsanlagen
- Gleich- oder Wechselspannungsansteuerung
- komplette und kompakte Baugruppe, bestehend aus jeweils zwei Schalteinheiten mit Kuhlkorper, Leistungsteil und Steuerelektronik
- keine zusatzliche Versorgungsspannung erforderlich
- keine Gerauschbildung
- einfache Montage

Introduction

The thyristor power module Thyro-C is a ready-to installation solution for **dynamic power factor correction equipment.** The following advantages are result of using the Thyro-C instead of classic switches, such as air contactors For example

- very high lifetime due to unlimited switching frequency
- smooth switching of the capacitors
- short switching delay
- suitability for realisation of real time power factor compensation equipment
- AC or DC control
- complete and compact assembly, each consisting of two modules with heat sink, power block and control electronics
- no auxiliary supply voltage needed
- no services necessary due to wearlessness
- noiselessness
- simple mounting

Typenubersicht

Range of types

Bestellbezeichnung Order Code	**2C 400-45 Q**	**2C 400-100 Q**	**2C 500-75 Q**
Nennschaltspannung (U_{eff}) Rated Voltage (U_{RMS})	400 V	400 V	525 V
Nennschaltstrom (I_{eff}) Rated Current (I_{RMS})	45 A	100 A	75 A

Einsatzgebiete

Der Thyristor-Leistungssteller Thyro-C kann eingesetzt werden in Verbindung mit:

- Speicherprogrammierbaren Steuerungen SPS
- Blindleistungsreglern oder Verfahrensreglern
- Computersystemen oder Prozeß-Leittechniken

Speziell fur:

- **schnelles und**
- **verschleißfreies Schalten**

Typische Anwendungsfalle sind z B :

- Krananlagen
- Aufzugsanlagen
- Punktschweißmaschinen

Range of operation

The thyristor power module Thyro-C can be used in combination with the following:

- Programmable logic controls (PLC)
- Power-factor controllers
- Computer systems

Especially for

- **fast and**
- **wearless switching**

Typical applications are:

- Cranes
- Elevators
- Welding machines

Betriebsart

Der Thyro-C ist geeignet zum Schalten von kapazitiven Lasten, also verdrosselten und unverdrosselten Kondensatoren

Der parallele Betrieb von Thyro-C's zusammen mit Kondensatorschutzen an einer Niederspannungsverteilung ist aufgrund der hohen Umladestóme nur bei verdrosselten Einheiten moglich.

Bitte lassen Sie sich von uns beraten, wenn bereits Kompensationseinrichtungen im Netz installiert sind

Funktionsprinzip

Der Steller besteht aus zwei Thyristormodulen, welche die Phasen L1 und L3 schalten Die Phase L2 wird nicht geschaltet
Die Thyristormodule konnen alternativ auch einphasig betrieben werden

Mode of operation

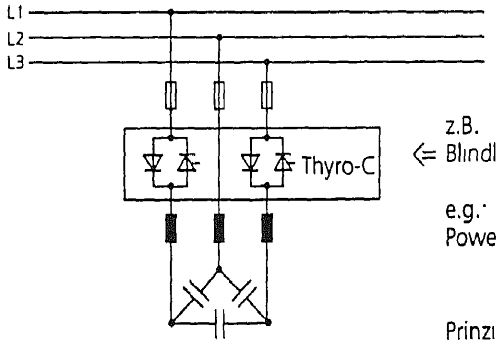
The Thyro-C is suitable for switching power capacitors with or without filter reactors.

The simultaneous operation of Thyro-C modules and capacitor contactors in one low voltage distribution is only allowed in power-factor correction equipment with filter reactors. This is necessary because of the high inrush overcurrents of capacitors switched by contactors.

Please contact us with any questions, if power factor correction equipment is already installed.

Working principle

The device consists of two thyristor modules, switching phase L1 and L3. Phase L2 is not switched.
Alternatively, the thyristor modules can be used for single phase applications



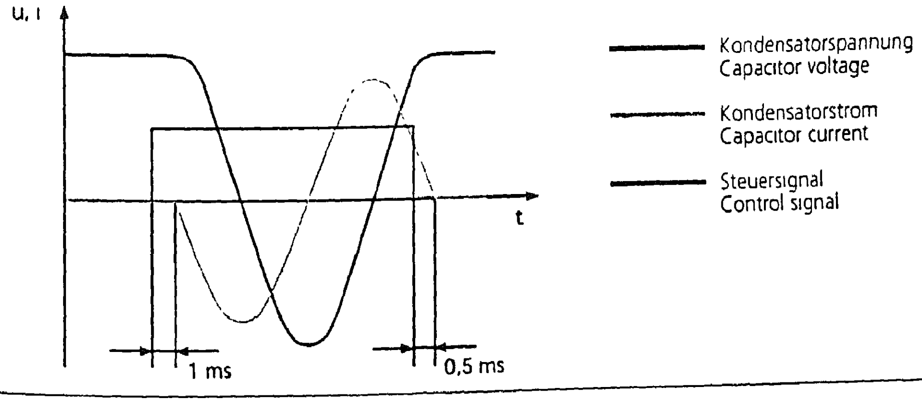
z.B.
⇐ Blindleistungsregler oder SPS

e.g.:
Power factor controller or PLC

Prinzipschaltbild / Connection diagram

Wird das Signal "EIN" an den Steuereingang des Thyro-C angelegt, schaltet die integrierte Steuerelektronik die Thyristoren im nachst folgenden negativen Stromnulldurchgang separat fur jede Phase zu Das Abschalten erfolgt ebenfalls im Stromnulldurchgang Transiente Schaltstorungen und Netzruckwirkungen werden durch dieses Prinzip unterbunden.
Während der Kondensator ausgeschaltet ist, bleibt er auf Netzscheitelspannung geladen und kann somit jederzeit wieder zugeschaltet werden

After feeding the control input of the Thyro-C with the signal "ON", the integrated electronics fire the thyristors separately for each phase in the next following negative zero current crossing The switch-off also occurs in the current zero crossing. Transient effects and reflections to the mains are suppressed due to this principle.
During the switch-off periods, the capacitors remain loaded with the mains peak voltage and can therefore be switched on again at any time.



Steuereingang

Der Thyro-C besitzt galvanisch vom Netz getrennte Steuereingänge (X1).
Das Steuersignal "EIN" wird durch die LED-Anzeige "ON" in der Frontplatte angezeigt.

Control signal

The Thyro-C has galvanicly separated control inputs (X1).
The LED installed in front side of the housing displays the control signal "ON".

Thyro-C	**Steuersignal (X1) / Control signal (X1)**	
	DC (1-3)	AC (1-2)
AUS / OFF	0 ... 3 V	0 ... 10 V
EIN / ON	10... 30 V / I_s =15 mA	50 ... 230 V / R_i = 20 kΩ

Kondensatorenentladung

Leistungskondensatoren müssen gemäß EN 60831 mit fest verbundenen Entladeeinrichtungen versehen werden. Da die Kondensatoren im ausgeschalteten Zustand permanent auf Netzscheitelspannung nachgeladen werden, dürfen generell nur Widerstände für die Entladung der Kondensatoren verwendet werden.

Wichtig: Auch wenn die Thyristorsteller keinen Strom führen, liegen die Kondensatoren auf Potential! Die Entladung der Kondensatoren erfolgt erst dann, wenn die Schaltstufe komplett vom Netz getrennt ist, also z. B. die Trenner geöffnet sind.

Inbetriebnahme

- Dimensionierung überprüfen
- NH-Stufen- und Anlagensicherungen sowie Steuersicherungen entfernen
- Thyro-C in senkrechter Position montieren. Ausreichende Kühlung gewährleisten (S. 5)
- Kunststoffabdeckungen abnehmen (Klammer an Vorderseite zur Seite drücken)
- Elektrische Verbindungen gemäß Anschlußschema (S. 7) herstellen. Drehfeldrichtung, Stromflußrichtung und Anzugsdrehmomente beachten!
- Kunststoffabdeckungen wieder aufsetzen
- Erst NH-Stufensicherungen dann die Anlagenhauptsicherungen wieder einsetzen. Hierbei auf korrekte Werte der Sicherungen achten. Achtung, die Kondensatoren sind sofort geladen !
- Steuersicherungen einsetzen
- Nach Zuschalten der Netzspannung ist der Thyro-C sofort betriebsbereit. Vor dem Zuschalten an das Netz bitte darauf achten, daß sich der Thyro-C im "OFF" Zustand befindet, also kein Steuersignal anliegt.

Discharge of capacitors

According to EN 60831, power capacitors have to be firmly connected with discharge devices. Because the capacitors are constantly recharged to mains peak voltage during switch-off periods (while the compensation stage is connected to mains), only resistors are allowed as discharge devices for the capacitors.

Important: Even when the thyristor switches are turned off, the capacitors are under tension. The capacitors are not discharged, until they are completely disconnected from mains, e.g. through opening of breaker.

Putting into operation

- Check the design of the equipment.
- Remove low-voltage fuses from the stages, the whole compensation unit and the control fuses (external)
- Set up the Thyro-C in an upright position. Please ensure a sufficient cooling for the device (pg. 5).
- Remove the plastic housings by pushing the clamp in the front side of the housing.
- Make the electric connections acc. to connection diagram (pg. 7). Please observe direction of rotating field, direction of current flow, and tightening torque!
- Fit plastic housing again to Thyro-C.
- Insert NH fuses into the stages first, then the fuses for the whole unit. Please observe correct size of the fuses. Attention: Capacitors are loaded immediately!
- Insert the control fuses.
- After switching on to mains the Thyro-C is immediately ready for operation. Please observe that the Thyro-C is in the "OFF" position, when connecting to mains.

Technische Daten

Schalthäufigkeit
16 Schaltungen pro Sekunde
(bei DC-Ansteuerung)

Schaltverzögerung
DC-Ansteuerung 1 ms 15 ms
AC-Ansteuerung 10 ms 25 ms

Einsatzbereich U_{RMS}
400 V: 320 460 V
525 V: 450 550 V

Netzfrequenz
50 / 60 Hz ± 3 Hz

Verlustleistung
ca 1,9 W/A

Leistungsaufnahme der Elektronik
ca 2 x 6 VA

Kriechstrecken
Steuereingang – Leistungskreis > 10 mm
Das Gerät kann an SELV-Kreise angeschlossen werden

Prüfspannung
EN 50178 (4/98)

Aufstellhöhe
≤ 1000m über NN

Betriebstemperatur
-10°C . + 45°C
bei vermindertem Strom bis +55°C
Stromreduzierung 2% / °C

Lagertemperatur
- 40°C + 85°C

Rel. Feuchte
EN50178, Tabelle7, Typ B

Geräteeinsatzbedingungen
Gerät ist ausgelegt nach:
EN 50178 (4/98), VDE 0106 Teil 100 (3/83)
Verschmutzungsgrad 2 nach VDE 0110 Teil 1 (1/89)
Überspannungskategorie Ü III nach EN 50178 (4/98)
Signalklemmen Klemmleiste X1:
Ausgelegt für sichere Trennung bis 525 V
Geräteanschlußspannung nach VDE 0160 5 6 (5/88)

Ausführung
Nach VDE 0558 Teil 1

Einbau
Senkrecht
Bodenfreiheit ≥100 mm
Deckenfreiheit ≥150 mm

Mechanischer Aufbau
Anschlußklemmen M6 von unten bzw oben

Drehmoment der Anschlußschrauben
3 Nm nach VDE 0609 Teil 1 (6/83)

Absicherung
Sicherungseinsätze zum Schutz von Halbleitern und für den Leitungsschutz,
z B. SiBA, Baureihe URL, siehe auch S. 6!
Empfohlen NH-Sicherungs-Lasttrenner-
3 x 160 A, Gr00

Technical specification

Switching sequence
16 switchings per second
(with DC-signal)

Turn-on / -off delay
DC-signal: 1 ms up to 15 ms
AC-signal: 10 ms up to 25 ms

Voltage range U_{RMS}
400 V 320 460 V
525 V. 450 . 550 V

Rated frequency
50 / 60 Hz ± 3 Hz

Losses
ca. 1,9 W/A

Power consumption of the electronics
app 2 x 6 VA

Leakage path
Control input - power circuit ≥ 10 mm
Device can be connected to SELV-circuits.

Test voltage
EN 50178 (4/98)

Operation altitude
≤ 1000m above sea level

Operating temperature
-10°C ... + 45°C
in case of reduced current up to +55°C
Reduction of rated current: 2% / °C

Storage temperature
- 40°C ... + 85°C

Humidity
EN50178, Tab. 7, Type B

Operating conditions
Device is designed under consideration of:
EN 50178 (4/98); VDE 0106 Part 100 (3/83)
Pollution category 2 acc. VDE 0110 Part 1 (1/89)
Overvoltage category Ü III acc. EN 50178 (4/98)
Terminal block X1: designed for safe disconnection up to 525 V
Connection voltage of device: VDE 0160 5 6 (5/88)

Design
Acc. VDE 0558 Part 1

Mounting
Orthogonal
Underclearance: ≥100 mm
Upperclearance: ≥150 mm

Mechanical design
Terminals M6 from top or from bottom

Torque of connecting screws
3 Nm acc. VDE 0609 Part 1 (6/83)

Fuses
Low voltage fuses for protection of semiconductors and lines,
e.g.: SiBA, series URL acc. pg. 6!
Recommended: Low voltage fuse breaker
3 x 160 A, Gr00.

Grenzwerte

Für den Thyro-C gelten die nachfolgend dargestellten Nenn- und Grenzwerte für Schaltströme und -leistungen

Design limits

The following nominal and limiting values for current and power are to be taken into account for the Thyro-C.

Typ Type	p	I_1	I_3	I_5	I_7	I_{RMS} Max.	$Q_{50/60HZ}$ 400V	$Q_{50/60HZ}$ 525V	P_V Max.	Absicherung Fuses
	[%]	[A]	[A]	[A]	[A]	[A]	[kvar]	[kvar]	[W]	
2C 400-45 Q	–*	36				45	25		86	3 x 50 A geeignet für Halbleiter siehe S. 5 suitable for semiconductors, see pg 5
	5,67	36		20	7					
	7	36		12						
	12,5	36	7	3						
	14	36	7	3						
2C 400-100 Q	–*	72				100	50		190	3 x 100 A geeignet für Halbleiter siehe S. 5 suitable for semiconductors, see pg 5
	5,67	72		41	14					
	7	72		24						
	12,5	72	14	5						
	14	72	14	5						
2C 500-75 Q	–*	58				75		53	143	3 x 80 A geeignet für Halbleiter siehe S. 5 suitable for semiconductors, see pg 5
	5,67	58		33	11					
	7	58		19						
	12,5	58	11	4						
	14	58	11	4						

* Nur zulässig, wenn
- Kompensationsleistung ≤ 35% der Anschlußleistung und
- kein hoher Oberschwingungspegel

Hinweis: Verdrosselungsgrad $p = \frac{X_L}{X_C} \cdot 100\ (\%)$

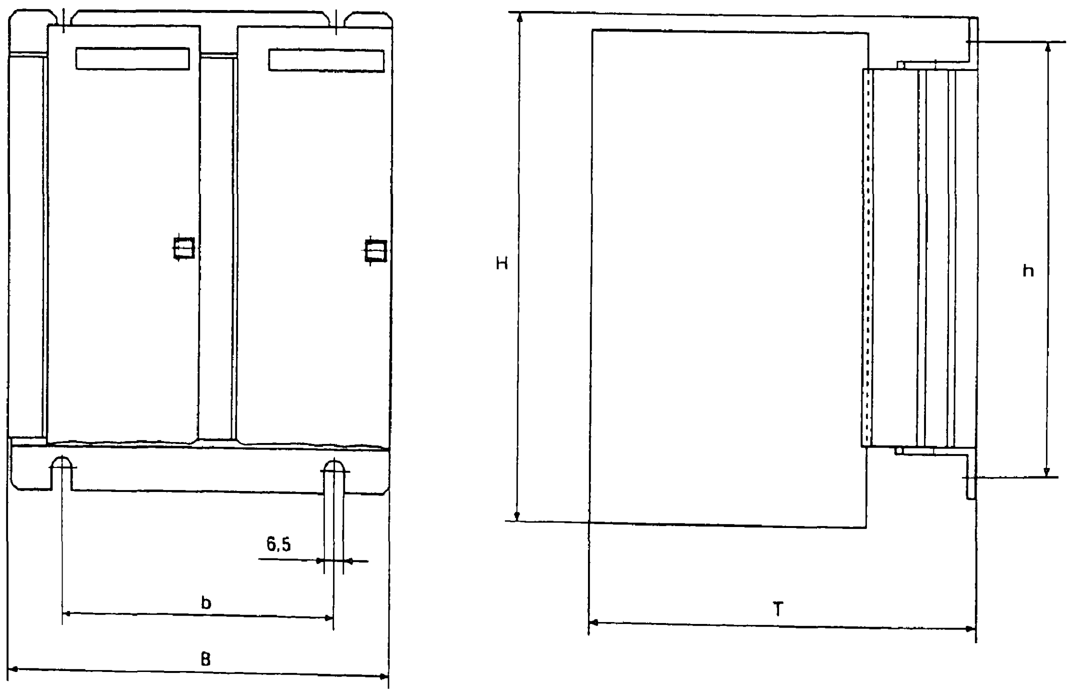
* Only allowed, if
- Power compensation load ≤ 35% of total load and
- small value of harmonics

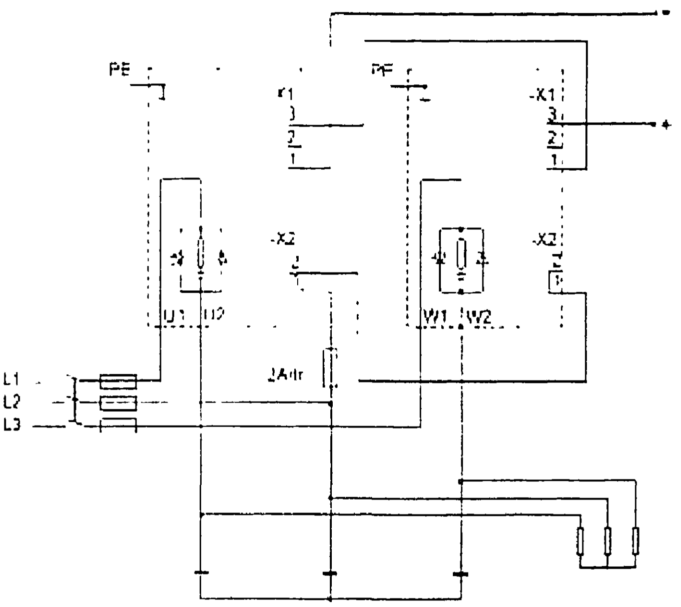
Calculation of detuning factor $p = \frac{X_L}{X_C}\ 100\ (\%)$

Abmessungen

Dimensions

Typ/Type	Abmessungen / Dimensions [mm]					Gewicht / Weight
	B	H	T	b	h	[kg]
2C 400-45 Q	140	173	135	100	150	2,1
2C 400-100 Q	170	173	135	125	150	3,7
2C 500-75 Q	170	173	135	125	150	3,6





DC-Ansteuerung
DC-Control

-X1/1-3 (1· u-/3· u+)
0-3V AUS/OFF
10-30V EIN/ON

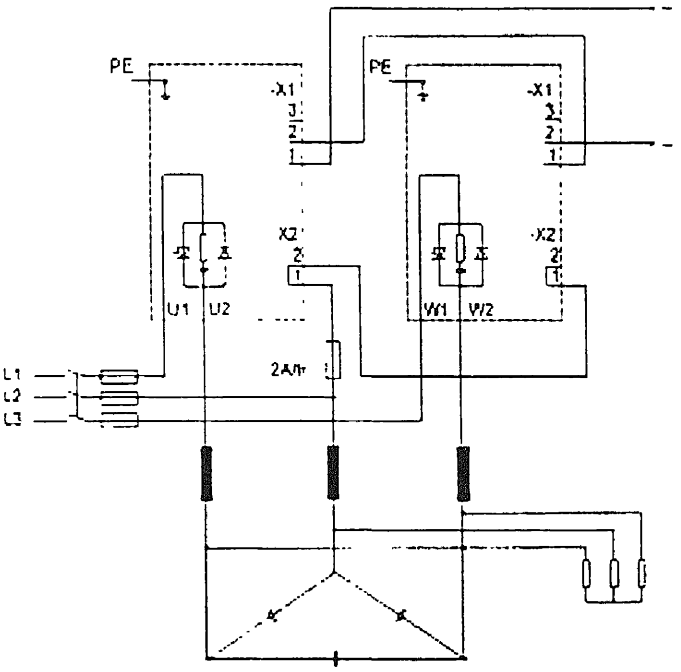
Trennstelle nach
EN 50178 (4/98)
Breaker acc
EN 50178 (4/98)

Entladewiderstande
Discharge Resistors

Last (Y-Schaltung z B)
Load (Y-connection e g)

Anschlußschema – DC Ansteuerung
-Kondensatoren unverdrosselt (z.B.)

Connection diagram – DC control
-without filter reactor protected capacitors (e g)



AC-Ansteuerung
(Voreinstellung)
AC-Control
(Presetting)

-X1/1-2
0-10V AUS/OFF
50-230V EIN/ON

Trennstelle nach
EN 50178 (4/98)
Breaker acc.
EN 50178 (4/98)

Filterkreisdrossel
Filter Reactor

Entladewiderstande
Discharge Resistors

Last (Δ-Schaltung z.B.)
Load (Δ-connection e.g)

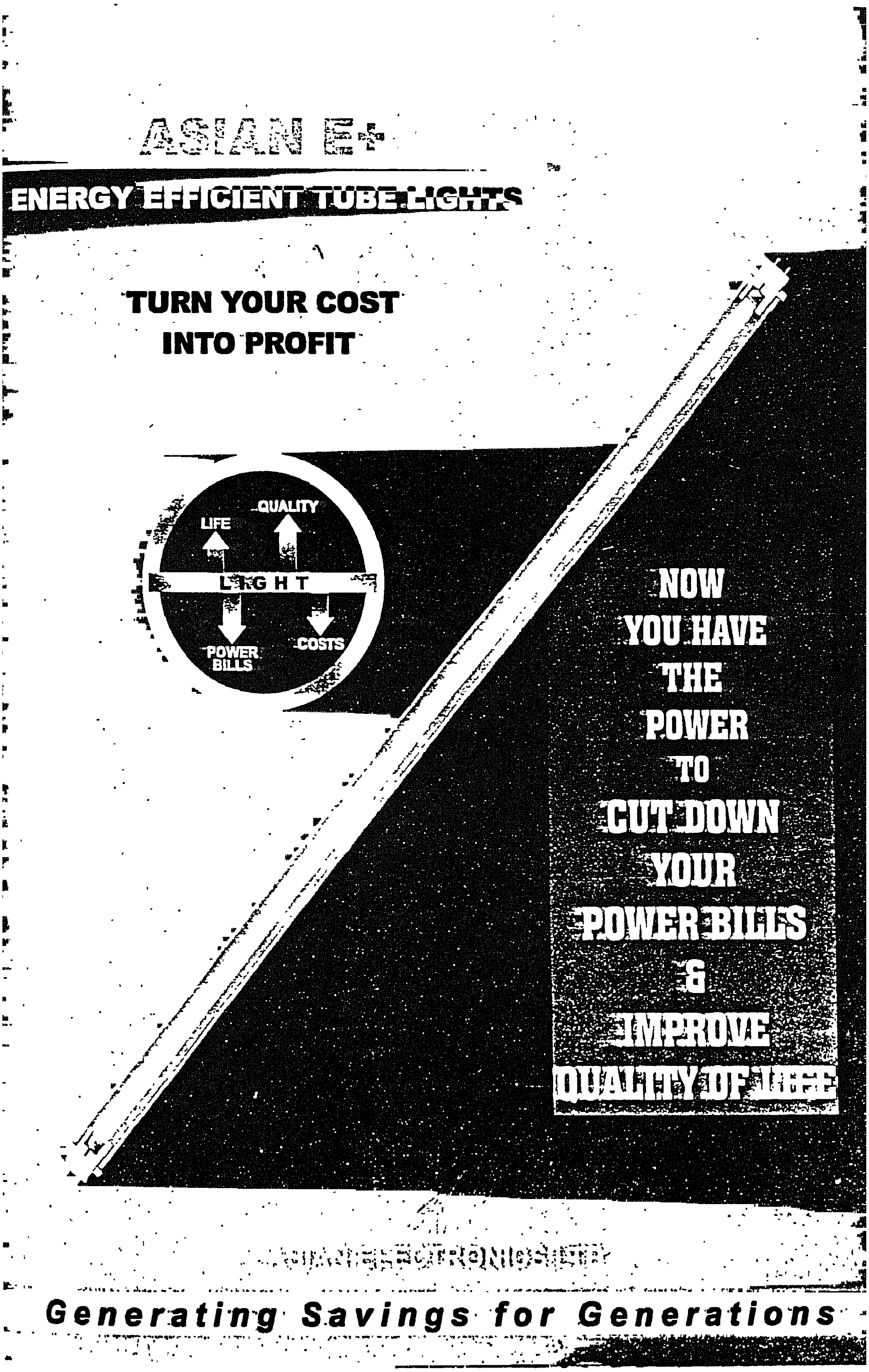
Anschlußschema – AC Ansteuerung
-Kondensatoren verdrosselt (z.B.)

Connection diagram – AC control
-with filter reactor protected capacitors (e g)

Hinweis Die Sicherung 2A/tr ist als Leistungsschutz vorgesehen

Remark Fuse 2A/tr is assigned for line protection

Annexure 4.3



ASIAN E+

ENERGY EFFICIENT TUBE LIGHTS

TURN YOUR COST
INTO PROFIT

LIFE
QUALITY
LIGHT
POWER BILLS
COSTS

NOW
YOU HAVE
THE
POWER
TO
CUT DOWN
YOUR
POWER BILLS
&
IMPROVE
QUALITY OF LIFE

ASIAN ELECTRONICS LTD.

Generating Savings for Generations

ASIAN E+
ENERGY EFFICIENT TUBE LIGHTS

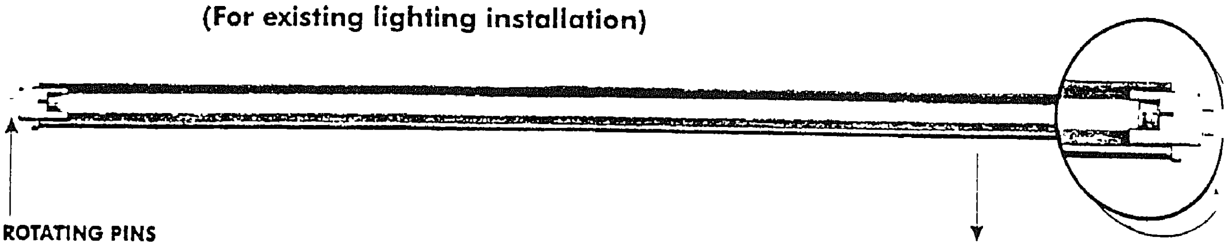
(WORLD WIDE PATENT PENDING)

Your Solution to Cut Down Power Bills...

Lighting load constitutes up to 17% of total electrical load in an industrial environment. E+ helps in cutting lighting load by about 45%. E+ is available both in Retrofit and Stand Alone Models E+ range of tube lights offer a host of innovative energy efficient lighting solutions.

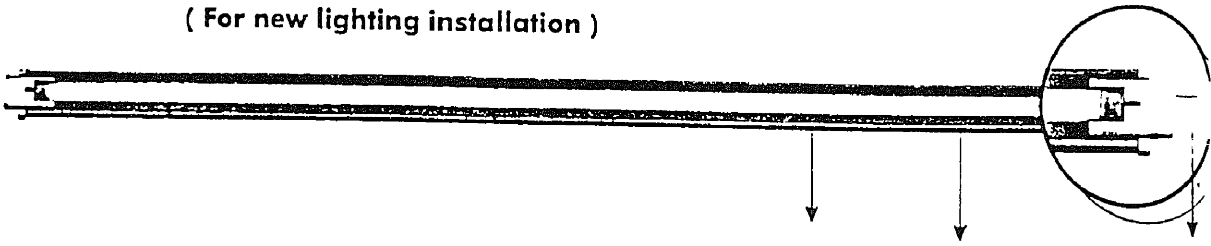
Model: RETROFIT

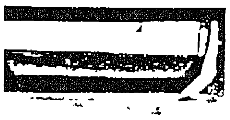
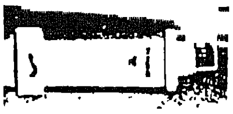
(For existing lighting installation)



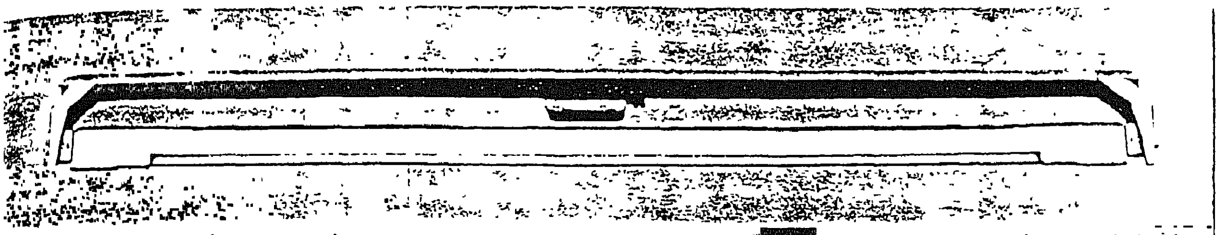
Model: STAND ALONE

(For new lighting installation)



MODEL	SPECIAL FEATURES	
Retrofit	Easy Installation • Straight replacement of existing tube light without any change in wiring or fitting & without removing the choke.	 With existing fitting
	• Unique Rotating Pins for easy installation.	 Rotating Pins
Retrofit / Stand Alone	Dimmer Switch • Option available for different settings of wattage consumption corresponding to different light levels.(refer highlights)	 Dimmer Switch
Stand Alone	Easy installation • Clamps provided for easy installation for surface & 45 degree angular wall mounting.	 Clamps for surface mounting Angular mounting

Generatin



Extend life of Lighting System...

Product range:

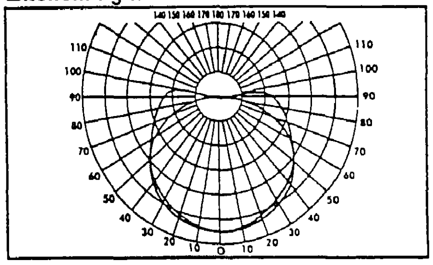
E+ tubelight's product range comprises 2' 24W, 4' 28W and 4' 54W versions as described below. These provide convenient energy efficient solutions in lieu of conventional lighting installations whether existing or proposed.

E+ Energy Efficient Option	in lieu of	Conventional tubelights + fixtures
Single 2' 24W E+ tube light	→	Twin 2' 20W FTLs + Fixture
Single 4' 28W E+ tube light	→	Single 4' 40W FTL + Fixture
Single 4' 54W E+ tube light	→	Twin 4' 40W FTLs + Fixture

- All versions of E+ have option of 3 colour temperatures to choose from... Warm White / Cool White / Day Light
- Dimmer Switch option also available

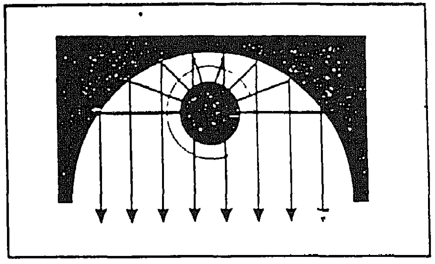
Highlights

Excellent light distribution characteristics



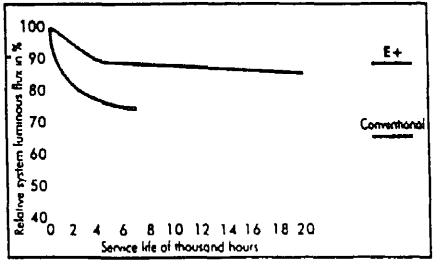
E+ delivers downward light out put ratio of over 70%, comparable to conventional FTL with mirror optics luminaire

High Luminous Efficiency



E+ delivers high luminous efficiency, due to considerably less obstruction

Lower Luminous Flux Drop



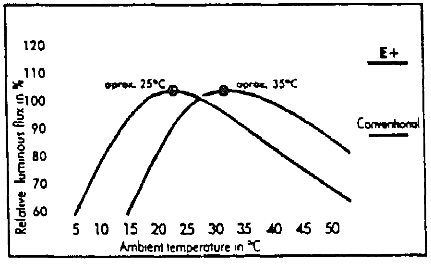
E+ offers significantly lower drop in luminous flux compared to the conventional tube light. T5 lamp has rated life of 18000 burning hrs. Conventional tube has rated life of 5000 burning hrs.

Dimmer Switch

Position	Wattage	Lux output % compared to conventional FTL fixture
▬	24 W	upto 100%
▬	26 W	upto 110%
▬	28 W	upto 120%

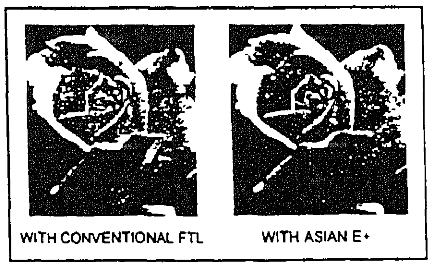
For different settings of wattage consumption corresponding to different light levels

Optimum Luminous Flux



Optimum luminous flux at 35°C in case of E+, as compared to 25°C of conventional tube light.

True Colour Rendition



High Colour Rendering Index of E+ shows objects in their true rich colours.

ASIAN

ASIAN ELECTRONICS LTD.

Improve Quality of life

Salient Features:

- E+ operates from 130V to 300V A.C, 50 Hz.
- Dimmer switch option available for different settings of wattage consumption.
- Flicker free starting & illumination.
- No stroboscopic effect.
- Hum free operation.
- Safety from shock hazards due to plastic housing.
- Programmed preheat ensures full utilisation of lamp life.
- Lamp current crest factor is less than 1.7.
- Chrome finished reflector delivers uniform light.
- High CRI reveals true colours & textures of objects.
- Harmonics content conforms to IEC.

Specification:

Input voltage range : 130V to 300V A.C, 50 Hz.

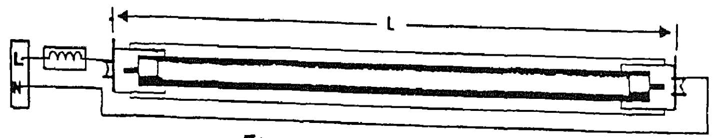
At nominal input voltage 230V A.C, 50 Hz

Product Type	Power Consumption	Input Current
E+ 24W	24W ± 1W	110 mA.
E+ 28W	28W ± 1W	130 mA.
E+ 54W	54W ± 2W	250 mA.

Common Parameters:

Power Factor	:	> 0.95
Rated Life T5 Lamp	:	18,000 Burning Hours
Rated Life Electronics	:	50,000 Burning Hours
DLOR Lux (Downward light Output Ratio)	:	Upto 20% higher than conventional tube light fixture.
Depreciation of DLOR of E+system	:	Upto 15% during the life of T5 lamp
Operating Temperature	:	Upto 50°C
Colour Rendering Index	:	85

Wiring Diagram for Retrofit



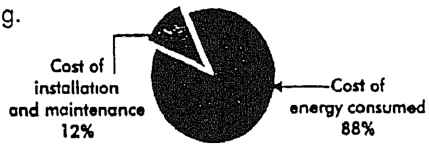
E+	L (mm.)
24W	590
28W	1200
54W	1200

o n s

Your Concerns

High Power Bills & Low Quality of Light

- Large lighting load.
- Penalty charges for overshooting maximum demand (MD) and/or low power factor.
- High maintenance cost due to frequent replacements.
- Low colour rendition of conventional tube lights.
- Cost of lighting.



Our Solution

ENERGY EFFICIENT **ASIAN** E+ TUBELIGHTS

- Cut your lighting load by about 45% .
- Reduce risk of penalty for exceeding MD and /or low power factor.
- Reduction in heat load on air conditioning - 5W / E+.
- Longer life with state of the art electronics and OSRAM T5 lamp .
- Improved quality of light due to high CRI of 85.
- Models available for existing / new lighting installations.
- Cost for changing over to E+ tubelight Rs. 15/- per Sqft.(average)
- Savings upto Rs. 100/- per Sqft. during E+ life cycle.

Pay From Savings

- **Available on outright purchase with 2 year guarantee.**
- **Installment credit plans also available**
  - Standard installment payment plan of two years.
  - Option of payment plans for different periods.
  - Guarantee during payment plan period.
  - Nominal bi-monthly payments.
  - No capital investment by the buyer.

ASIAN E+

ENERGY EFFICIENT TUBE LIGHTS

Efficiency comparison

Parameter	E+ 28W	Conventional 40W FTL
Power consumption	28 ± 1W	53 W or more
Power factor	0.95 and higher	0.5 to 0.75
Rated Tube life	18000 burning hours	5000 burning hours as per IS
HF noise/harmonics	Conforming to IEC	Present
Striking voltage	Less than120 V	More than 180 V
VA	30	81
CRI	85	55
Temp for optimum luminous output	35°C	25°C
DLOR Lux	upto 20% higher than conventional tube light of 40W/36W	

Notes 1 Table based on data available from market
2 These figures do not correspond to any specific make

Guide To Calculate Power Savings

Parameters:

• Energy consumed by a conventional flourescent tube light assembly	53 Watts
• Energy consumed by 4' E+ 28W tube light	28 ± 1 Watts
• Average power savings / E+	24 Watts
• Power tariff	Rs 4.50/Kwh
• Rated life of conventional tube	5000 Burning Hours
• Rated life of T5 28W tube	18,000 Burning Hours
• Rated life of electronics	50,000 Burning Hours

Model Calculations

	Description			
A.	Usage of E+ per day	- Hrs	12	24
B.	Usage of E+ per year of 300 working days	- Hrs	3600	7200
C.	Usage of E+ during life cycle of T5 lamp (18000/**B**) X 12	- Months	60	30
D.	Energy saved by each E+ tube light due to 24 Watt reduction in power consumption during T5 lamp life cycle of 18000 hours	- Kwh	432	432
E.	Energy savings per E+ during T5 life cycle @ Rs 4 50 per Kwh - **D** X 4.50	- Rs.	1944	1944
F.	Savings due to avoided replacement of conventional fluorescent tube lights during the T5 lamp life of 18000 burning hours. (@ 5000hrs. life, 4 Nos conventional tube lights each costing Rs 50/-)	- Rs	200	200
G.	Total savings achieved per E+ (**E+F**) in 18,000 Hrs	- Rs	2144	2144
H.	Savings per month per E+	- Rs	36	72
I	Savings per month per E+ with dimmer switch at "L" position (24 W)	-Rs.	43	86

During full rated life span of E+ System, the savings would work out to over Rs. 5,000 per E+ system. In addition there is a reduction in heat load on air conditioning- 5 watts per E+

Depending on the usage hours of E+ and wattage consumption option through dimmer switch, the savings can be easily computed for your establishment

Visit our interactive website www.asian-eplus.com for live answers to your queries on savings with E+ .

As continuous product upgradation efforts are ongoing, the product specification given may undergo marginal variations

Generating Savings for Generations

ENERGY SAVING PRODUCTS AND SYSTEMS
ASIAN

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Near Lions Hall, Mithakhali,
Ellisbridge Opp Ashoka
Chambers Ahmedabad - 380 006
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Fax 91-79-6564673
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Calcutta - 700 068
Ph 91-33-4131825 ,
Fax 91-33-4735619

CHENNAI
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Chennai - 600 018
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NASIK
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646982
Fax 91-260-642993

BASIC CONCEPT

Annexure 5.1

Application Considerations for AC Drives

DENNIS P. CONNORS, MEMBER, IEEE, AND DENNIS A. JARC, MEMBER, IEEE

Abstract—**General application considerations for ac variable-frequency drives are discussed. A review of induction motor characteristics and adjustable frequency controller fundamentals is presented as a background for applying the drives. In addition, a brief review of the types of controllers available is provided. General application guidelines are then presented.**

INTRODUCTION

VARIABLE-frequency drives are among the newest products in the family of adjustable speed drives, and a need exists for general application guidelines. Proper application of controllers to standard induction motors to obtain variable-speed operation requires a detailed understanding of the application requirements. This would include factors such as torque requirements, duty cycle, and speed range.

Once the application requirements are defined, the controller kilovolt ampere can be determined and the proper motor selected. The primary concern in sizing the controller kilovolt ampere involves providing sufficient current to produce the required torque. A primary concern in selecting the proper motor involves ensuring that the motor temperature rise does not exceed its insulation rating. These points are discussed in the following.

MOTOR CHARACTERISTICS

Fig. 1 shows typical speed-torque and current characteristics for a 25-hp National Electrical Manufacturers Association (NEMA) Design B 1800-r/min motor started across the line and operated on fixed voltage and fixed frequency. This motor has the ability to produce 174 percent of full load torque for starting and a maximum of 220 percent of full load torque at its breakdown point. The inrush current at starting is 524 percent of full load current and decreases to 100 percent at 100 percent torque.

Fig. 2 magnifies the region around the 100 percent torque point and shows the current required to produce various torques. It can be seen that the torque and current are not proportional above 150 percent torque. For this reason most adjustable frequency controllers have only 150 percent maximum current capability.

Fig. 3 shows the NEMA torque requirements for 1800-r/min Design B motors. As can be seen, the locked rotor (starting) torque and breakdown (overload) torque do not

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Paper PID 83-5, approved by the Pulp and Paper Industry Committee of the IEEE Industry Applications Society. A version of this paper was presented at the 1982 Pulp and Paper Industry Technical Conference, Niagara Falls, ON, Canada, June 9-11. Manuscript released for publication Janauary 12, 1983.

The authors are with the Reliance Electric Company, Cleveland, OH 44117.

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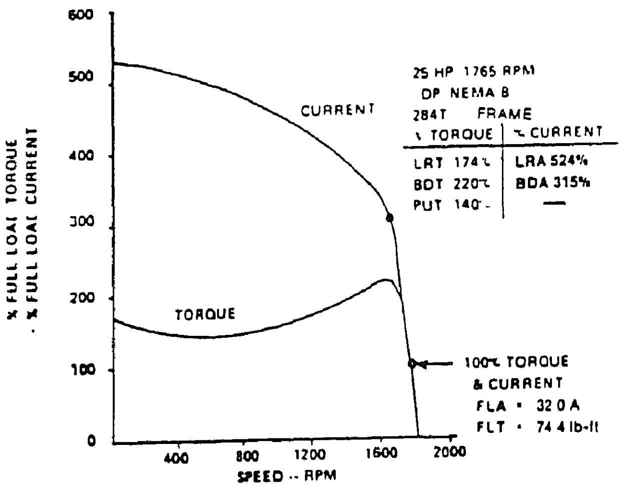

Fig. 1. Typical induction motor characteristics.

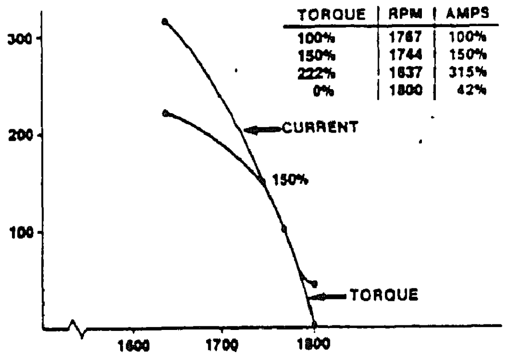

Fig. 2.

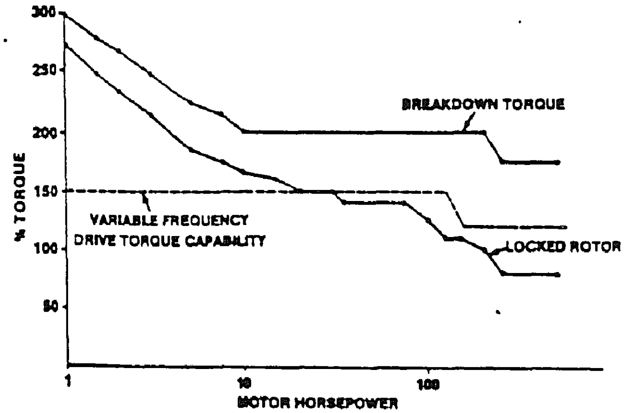

Fig. 3. NEMA torque requirements for 1800-r/min Design B motors.

remain constant for motors as they change horsepower. It is also evident that if an adjustable frequency controller is designed to produce a maximum of 150 percent torque out of the motor, the variable-frequency drive might need to be oversized in order to provide equivalent torque capability. For this reason, the overload torque must be checked for all horsepowers, and the starting torque needs only to be checked below 20 hp on retrofit applications.

The rated torque, horsepower, and speed are related by the following equation:

$$T = \frac{5250}{\text{speed}} \times \text{hp}.$$

The speed is a function of the number of poles and the applied frequency as shown:

$$\text{speed} \propto \frac{Kx \text{ frequency}}{\text{poles}}$$

The torque is proportional to flux density in the air gap which is proportional to the volts/hertz (V/Hz) applied to the motor:

$$T \propto \phi_{\text{air gap}} \propto \text{V/H}.$$

By referring to these two equations, it can be seen that an induction motor will run at variable speed and produce constant torque over its speed range by varying the voltage with the frequency.

ADJUSTABLE FREQUENCY CONTROLLER CHARACTERISTICS

In order to produce constant torque, the controller must maintain a constant flux and consequently a V/Hz ouput in some manner as shown in Fig. 4. As the frequency is varied, the motor has a particular speed, torque, and current characteristic for each frequency as shown in Fig. 5 for a constant V/Hz output.

As the frequency decreases, the maximum torque available and the breakdown torque decrease. This is caused by the stator resistance voltage drop which becomes significant at low frequencies where low voltage would be applied. This reduction in maximum torque at low frequency can be overcome by introducing an offset or voltage boost at low frequency. This voltage would be adjusted to offset the resistive voltage drop of the stator winding. The resulting V/Hz characteristic is shown in Fig. 6. Once the offset voltage is adjusted, the motor will develop constant torque over the speed range.

It should also be noted that, typically, the torque that the motor developed over the entire speed range is between the breakdown and synchronous speed point. The locked rotor and pullup torque is not encountered when an induction motor is started from rest and run from a controller. The speed-torque and current characteristics shown in Fig. 1 would apply only to full voltage starting.

In addition, the current supplied by the controller is only that amount necessary to meet the torque requirements. Since the controller output generally follows a V/Hz curve, the motor never sees locked-rotor current. This results in a soft start characteristic and is one of the advantages of using an adjustable frequency controller.

Up to this point, only constant torque operation has been discussed. The V/Hz curve, however, can be adjusted to provide constant horsepower operation above synchronous speed. Fig. 7 shows the resulting speed-torque curve of an induction motor and the associated controller V/Hz output. Constant torque is provided below 60 Hz and constant horsepower above 60 Hz.

CURRENT AND TORQUE RELATIONSHIP

Since the motor typically operates between its breakdown and synchronous speed points, the current and torque

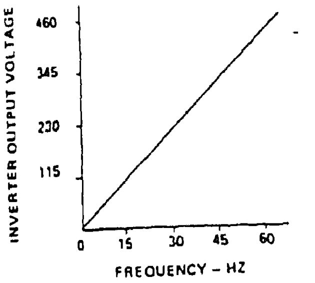

Fig. 4. V/Hz without offset voltage.

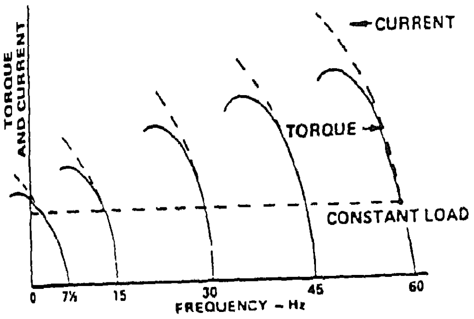

Fig. 5. Torque and current versus frequency for constant load and no offset voltage.

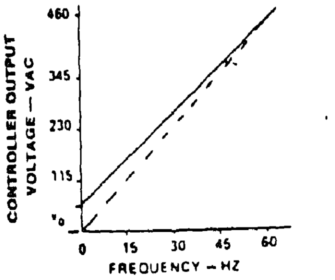

Fig. 6. V/Hz with offset voltage.

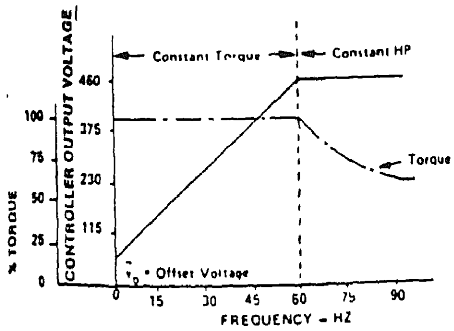

Fig. 7. Adjustable frequency controller characteristics.

relationship shown in Fig. 2 would apply. Unlike dc drives where armature current and torque are nearly proportional, the stator current and torque are not proportional above 150-percent torque.

Typically, a controller has a 1-min current rating of 150 percent of its continuous rating. This means that the motor will develop 150 percent torque, but if more torque is required, a substantially larger controller would be required.

An evaluation on an individual basis is necessary to determine the amount of torque produced with 150 percent current. For many applications where the starting torque exceeds 150 percent, the kilovolt ampere rating of the controller is based on its 1-min rating rather than its continuous rating. It is important to remember that a controller is a current rated source of power. Rating it only by horsepower may result in its misapplication due to limited overload torque capability.

In addition to its continuous and 1-min rating, a controller also has an instantaneous rating, an instantaneous electronic trip (IET) condition. This peak rating is typically 300 percent of the continuous rating. Since the output current of a controller is nonsinusoidal, the peak is approximately 2.0 times the sine wave rms value. Transient load changes, or the peak value of starting current of the load, must also be within the IET point when determining the kilovolt ampere rating of the controller.

TYPES OF ADJUSTABLE FREQUENCY CONTROLLERS

The information just discussed would generally apply to any of the three types of controllers available: variable-voltage input (VVI), current source input (CSI), and pulsewidth modulated (PWM) controllers. Each of the controller types is discussed in the following.

VVI

A variable-voltage input controller typically utilizes a phase controlled rectifier to generate the required dc voltage level for the desired V/Hz ratio. This voltage is then filtered by a large dc link reactor and capacitor before being inverted to the required frequency for the desired motor speed. The frequency of the output is determined by the switching of the transistors or semiconductor-controlled rectifiers (SCR's) in the inverter section. A block diagram of this approach and the associated output voltage is shown in Fig. 8 for the six-step output.

This type of controller produces harmonic voltages. The resulting harmonic currents depend on the load impedance at the harmonic frequency. These harmonic currents are limited by the induction motor leakage reactance. Induction motors with higher values of leakage reductance will have less harmonic currents and lower harmonic losses.

CSI

A current source input controller, Fig. 8, also typically uses a phase controlled rectifier to generate adjustable dc voltage. The phase controlled rectifier produces the required voltage which is then filtered by a large dc link reactor to constant current. The inverter section then produces the required variable-frequency current, and the motor voltage follows the current.

A typical six-step output is shown in Fig. 9. This type of controller produces harmonic currents, and the harmonic voltages are limited by the induction motor leakage reactance. In contrast to a variable-voltage input controller, though, lower leakage reactance results in reduced harmonic voltages and hence lower losses.

PWM

A pulsewidth modulated controller, Fig. 10, is a controller which uses a fixed diode rectifier with a small filter capacitor

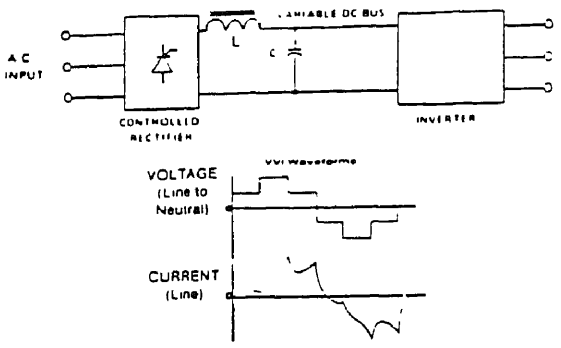

Fig. 8. Variable-voltage input controller.

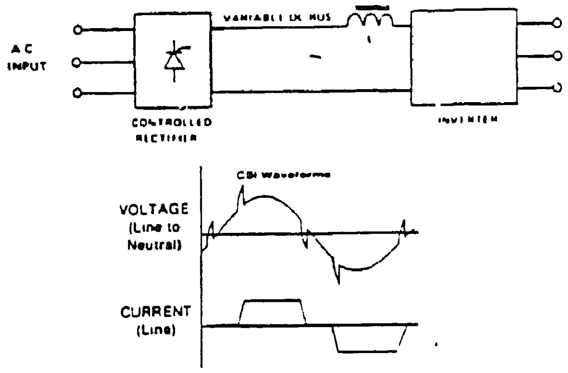

Fig. 9. Current source input controller.

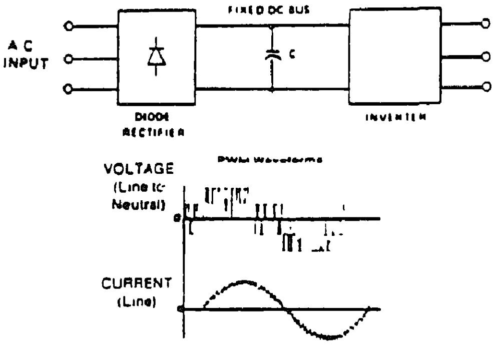

Fig. 10. PWM inverter.

to generate constant potential dc. The inverter section is controlled to produce variable voltage and variable frequency as shown in Fig. 9. This technique generally uses higher switching frequencies at lower motor speeds and lower switching frequencies at higher speeds.

This type of controller produces harmonic voltages as is the case of a variable-voltage input controller. The harmonic content, however, is dependent on switching frequencies, and the harmonic content is generally much lower than for a VVI. Higher values of leakage reactance for induction motors are desirable for limiting harmonic currents.

APPLICATION REQUIREMENTS

Definition of the application is the key to successful operation of a variable-frequency drive. A typical list of questions, certainly not intended to be all inclusive, is as follows.

1. What is the driven load?
   - a) Centrifugal pump.
   - b) Extruder.
   - c) Conveyor.
2. What are the load requirements?
   - a) Variable torque.
   - b) Constant torque.
   - c) Constant horsepower
   - d) Starting torque.
   - e) Overload torque.
3. What is the horsepower and speed range?
   - a) Above or below base speed.
4. Is an existing motor to be used?
   - a) Nameplate voltage and current.
   - b) Insulation class.
   - c) Current and torque data.
   - d) NEMA design characteristic.
5. What are the environmental considerations?
   - a) Ambient temperature range.
   - b) Indoors.
   - c) Outdoors.

The above information is necessary to determine the kVA rating of the controller and the correct motor for the application. Two typical applications are now discussed.

Variable Torque Applications

Variable torque applications are by far the easiest to work with. Centrifugal pumps, centrifugal compressors, and fans are typical examples. The torque varies likewise the square of speed as shown in Fig. 11. Since the starting torque requirements are very low, very little, if any, offset voltage is required to start the drive. This is valid for all pumping applications as long as the fluid being pumped has a minimal solids content.

However, if solids are present, as can occur with a wood pulp slurry pump application, the solids may settle while the pump is idle. A high starting torque requirement might exist when the pump starts from rest. This must be taken into account when determining the kilovolt ampere rating of the input controllers. Again, application details are essential even when driving pumps.

Fans with high inertia require some caution. The adjustable frequency controllers must have sufficient current capacity to accelerate the motor in a reasonable amount of time to avoid overheating the motor and controller. The acceleration time must be evaluated commensurate with the load requirements.

For centrifugal type loads, the torque requirements vary with the square of the speed, and the power requirements vary with the cube of the speed. Consequently, the maximum load would generally occur at full speed, and the required input controllers kilovolt ampere would then be

$$\text{kilovolt ampere} = \frac{\sqrt{3} \times \text{line-to-line voltage} \times \text{rated current} \times 1.1}{1000}.$$

The rms sine wave current is increased by 10 percent to take into account that the current from the input controllers is nonsinusoidal. Using the data from the 25-hp motor, the re-

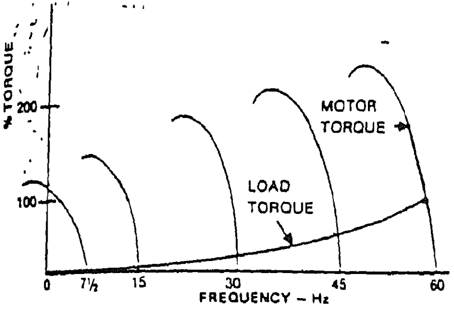

Fig. 11. Torque versus freqeuncy for variable torque load and no offset voltage.

quired kilovolt ampere would be

$$\frac{\sqrt{3} \times 460 \times 32 \times 1.1}{1000} = 28 \text{ kVA}.$$

Constant Torque Applications

Drives requiring constant torque operation are a little more difficult to apply. Typically, extruders, conveyors, and positive displacement pumps represent this type of load. Not only is the torque requirement constant, as shown in Fig. 5, but occasionally the starting torque requirements might exceed 150 percent. Practically speaking, the determination of the starting torque requirement is difficult. Historical data or existing drives may aid in determining it.

Let us look at a typical conveyor application:

a) 25 hp, 1765 r/min,
b) speed range 10:1 (6–60 Hz),
c) 175 percent starting torque,
d) constant torque load.

If the air gap flux is held constant, then the full load current will be approximately constant over the required speed range, and the required input controllers kilovolt ampere would be 28 kVA as calculated for the centrifugal load.

The starting torque, however, requires approximately 71 A or 218 percent of full load current as read from the graph in Fig. 2. In order to determine the kilovolt ampere required for starting, the overload rating of the input controllers (typically 150 percent of continuous) may be used with the result that the continuous kilovolt ampere rating of the input controller is

$$\text{kilovolt ampere} = \frac{\sqrt{3} \times 460 \times 71 \times 1.1}{1000 \times 1.5} = 41 \quad \text{kVA}.$$

Consequently, the required input controller kilovolt ampere is determined by the starting torque requirements and not the running load requirements.

MOTOR APPLICATION

The primary concern with operating standard induction motors on adjustable frequency controller power is the additional temperature rise over sine wave temperature rise. This additional heating is caused by the harmonic content of the input controller output and the reduced cooling at speeds lower than full load speed.

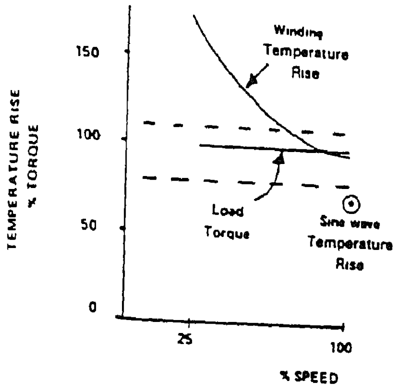

Fig. 12. Typical motor temperature rise at rated torque.

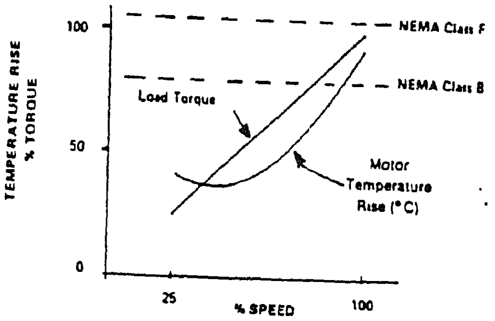

Fig. 13. Typical motor temperature rise for variable torque load.

Fig. 12 shows a typical temperature rise for an induction motor operated at its full load torque-rating over a 4:1 speed range. The temperature rise limitations are exceeded for Class B insulation at 60 Hz and for Class F insulation at approximately 75 percent speed. Consequently, a derating is generally necessary to remain within the allowable temperature rise. This derating must consider factors such as speed range, load characteristics, type of adjustable frequency controller, motor leakage reactance, and motor speed-torque characteristics.

A typical temperature rise for a variable torque load is shown in Fig. 13. This might correspond to a centrifugal load. Since the torque requirements decrease rapidly with speed reduction, induction motors might be operated at the nameplate horsepower within Class F rise limitations.

A typical temperature rise curve for a constant torque load is shown in Fig. 14. The testing we have done indicates that it is necessary to derate a standard Class B insulated motor by 20 percent of the nameplate horsepower rating from 60 to 30 Hz and by approximately one-percent Hz below 30 Hz. A standard Class F insulated motor would provide its nameplate rating over a 2:1 speed range to 30 Hz and would follow a one-percent Hz derating below 30 Hz. Better performance, however, could be obtained by using a high efficiency design motor on a given application.

Limiting the additional induction motor temperature rise on adjustable controller power is essentially a matter of reducing the harmonic related losses. Thus better performance on VVI or PWM input controllers can be obtained by designing the required horsepower rating in a larger frame size. This provides additional material for heat dissipation and allows increased leakage reactance, which limits harmonic losses, to be designed into the motor. Using standard over-

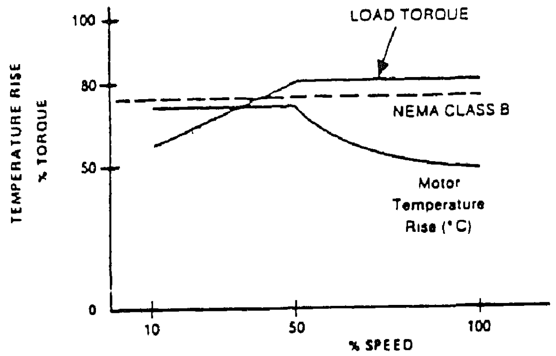

Fig. 14. Typical motor temperature rise for constant torque load.

framed motors on VVI or PWM input controllers would not generally be recommended because leakage reactance decreases with increasing horsepower for standard motor designs, and consequently, harmonic losses would increase. Better performance can be obtained on a CSI controller, however, by using a larger horsepower standard motor design. The lower leakage reactance would limit the harmonic losses associated with the CSI controller output. A CSI, however, would not lend itself well to operating smaller horsepower ratings, whereas a VVI or PWM would be able to operate smaller horsepower ratings.

For any given motor frame size, the losses will vary depending on the NEMA speed torque characteristics. The various speed torque characteristics are associated with different induction motor impedance characteristics which can affect losses. In general Design B characteristics would be more desirable for VVI and PWM controllers, and Design A characteristics would be more desirable for CSI controllers. NEMA Design C and D motors would not be recommended for use on any adjustable frequency controller.

Thus, while it is true that standard induction motors can be used on adjustable frequency controller power for adjustable speed operation, it is important that the motor characteristics be reviewed to determine that the required operation can be achieved on input controller power. As the application requirements become more demanding, starting torques greater than 150 percent, speed ranges greater than 10:1, high transient loads, etc., are noted, a detailed computer study of the motor with the adjustable frequency controller may be necessary.

CONCLUSION

Variable-frequency drives can be used successfully for many applications once the drive requirements are defined. The adjustable frequency controller replaces a large source of current and as such is current limited rather than horsepower limited. For drives other than those represented by most centrifugal type loads, application details are essential to determine the proper hardware. Both the adjustable frequency controller and motor must be evaluated for a particular requirement. Once the application requirements are defined and the combined controller and motor characteristics understood, successful operation of the drive can be assured.

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Annexure 6.1

(a) Estimation of total compressed air leakage in plant (Using compressor #5)

Table A6.1a Estimation of compressed air leakage

Initial pressure in the in-built gauge = 5.25 kg/cm^2 (g)

Final pressure in the in-built gauge = 6.50 kg/cm^2 (g)

Volume of air receiver = 2.72 m^3

Free air delivery of compressor (designed) = 16.98 m^3/min

Average time taken to fall in air pressure (6.5 kg/cm^2 (g) to 5.25 kg/cm^2 (g), in air receiver) = 1.65 min (99 secs)

Average time to built up air pressure (5.25 kg/cm^2 (g) to 6.5 kg/cm^2 (g), in air receiver) = 0.72 min (43.2 secs)

Compressed air leakage 30.4%

Compressed air leakage (based on actual FAD) = 5.14 m^3/min (~ 182 cfm)

Specific power consumption (based on actual FAD) = 4.04 kW/m^3/min

Loss due to leakage = 21.5 kW

Arresting the leakage and allowing only 10% leakage in the system can save about 65% of this loss.

Electrical savings per annum (@ 5037 working hr per annum) = 70200 kWh

Monetary savings per annum (@ Rs 4.19/kWh) = Rs 315850

Monetary savings per hour = Rs. 59

(b) Revised estimation (in-house) of total compressed air leakage in plant (Assuming compressor #5 in use)

Table A6.1b Estimation of compressed air leakage

Initial pressure in the in-built gauge = 5.25 kg/cm^2 (g)

Final pressure in the in-built gauge = 6.50 kg/cm^2 (g)

Volume of air receiver = 2.72 m^3

Free air delivery of compressor (designed) = 16.98 m^3/min

Average time taken to fall in air pressure (6.5 kg/cm^2 (g) to 5.25 kg/cm^2 (g), in air receiver) = 0.5 min (30 secs)

Average time to built up air pressure (5.25 kg/cm^2 (g) to 6.5 kg/cm^2 (g), in air receiver) = 0.416 min (25 secs)

Compressed air leakage 45.4%

Compressed air leakage (based on actual FAD) = 7.69 m^3/min (~ 272 cfm)

Specific power consumption (based on actual FAD) = 4.04 kW/m^3/min

Loss due to leakage = 32.2 kW

Arresting the leakage and allowing only 10% leakage in the system can save about 75% of this loss.

Electrical savings per annum (@ 5037 working hr per annum) = 121970 kWh

Monetary savings per annum (@ Rs 4.19/kWh) = Rs 511060

Monetary savings per hour = Rs. 101

3 Avoiding leaks and energy wastage

The air distribution system

The air mains and their associated branches, hoses, couplings and other accessories offer considerable opportunities for energy conservation.

Excessive pressure drop due to inadequate pipe sizing, choked filter elements, improperly sized couplings and hoses represents energy wastage as do leaking pipe joints and couplings.

Pressure loss in pipes

Generally a ring main is the best arrangement for a factory compressed air system. It is essential that pipe sizes should be sized to prevent excessive pressure drop and Table 1 demonstrates the penalty in energy wastage if the pipes used are too small.

To avoid excess energy loss maximum air velocities in pipes should not exceed 6 m/s (1,200 ft/min) although higher air velocities can be permitted in branch lines of total lengths less than 15 m. Table 2 gives examples of maximum recommended air-flow rates for various sizes of pipe at the normal compressed air mains pressure of 7 bar gauge (100 psig) for both main line piping and branch mains of limited length.

Pressure can be lost through accumulations of condensed water and scale in the system, hence the mains should slope to strategically located

Table 1 Pressure losses in air mains

Pipe normal bore mm	*Pressure drop (bar) per 100 metres*	*Equivalent power losses kW*
40	1.8	9.5
50	0.65	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

drain legs equipped with automatically operated drain valves to avoid the air wastage which frequently occurs with manually operated drain valves.

Leakage

Another major opportunity to save energy is in the prevention of leaks in the compressed air system. Leaks frequently occur at air receiver relief valves, pipe and hose joints, shut-off valves, quick release couplings, tools and equipment.

In most cases they are due to poor maintenance rather than improper installation *and if the resultant power wastage were fully appreciated it would be seen that any expenditure on sealing le could be easily recovered in energy savings.*

Table 3 Power wastage through leaks

Hole diameter (true size)		*Air leakage at 7 bar gauge (100 psig)*		*Power requir. to compress a being waste.*
mm	*in*	*dm^3/s*	*scfm*	*kW*
0.4	1/64	0.2	0.4	0.1
1.6	1/16	3.1	6.5	1.0
3.0	⅛	11.0	23.2	3.5

Table 3 gives examples of the approximate pov wasted by leaks of various sizes at the normal airline pressure of 7 bar gauge (100 psig) and si it is very easy to have ten or more leaks in any system, the power wastage can be considerabl Detection of large leaks is simple because they audible, but as large leaks usually start as small leaks, regular checking of joints, unions etc., wi soapy water will soon identify them.

A simple method of measuring the total leak of the system, which should be part of your planned maintenance programme, is by making use of the known free air delivery capacity of yo

Table 2 Maximum recommended air-flow rates

Medium weight pipe BS 1387		*Maximum recommended air-flow at compressor house pressure of 7 bar gauge (100 psig)*			
Nominal bore		*Main lines*		*Branch lines (not exceeding 15 m (50 ft))*	
mm	*in*	*dm^3/s†*	*scfm**	*dm^3/s†*	*scfm**
6	⅛	1	3	3	6
8	¼	3	6	6	13
10	⅜	5	10	13	29
15	½	10	20	25	54
20	¾	17	35	40	80
25	1	25	54	70	150
32	1¼	50	100	150	315
40	1½	65	135	220	470
50	2	100	220	425	900
65	2½	180	375	680	1450
80	3	240	500	1230	2600
100	4	410	875	–	–
125	5	610	1300	–	–
150	6	900	1900	–	–

†dm^3/s = cubic decimetres per second free air
*scfm = standard cubic feet per minute free air
Both measured at Standard Atmospheric Conditions – 1013 mbar (14.7 psig) at 20 °C (68 °F)

compressor and an ordinary watch. The procedure differs with different types of compressor.

With reciprocating compressors, shut off all air operated equipment, run the air compressor until the system reaches full line pressure and the compressor unloads; note the time. Due to air leaks the system pressure will fall, and the compressor will come on-load again; note the time. The period for which the compressor is 'on load' and 'off-load' should be recorded at least four times to give a mean value of each.

Let T minutes = Time 'on-load'
Let t minutes = Time 'off-load'
Let Q = Delivered free air capacity of compressor in litres/sec
Let L = Total system leakage in litres of free air per second

$$L = \frac{Q \times T}{(T + t)} \quad \text{litres/sec}$$

$$\text{Power wasted } \frac{L}{3} \quad \text{kW}$$

With rotary vane and screw compressors the technique is modified in that the system is charged for one minute, the compressor is then stopped until the system pressure has dropped one bar. The machine is restarted and the time taken to recover one bar pressure is noted and the rate of leakage can then be calculated from the free air delivery rate of the compressor.

Air dryers and air reheating

Air dryers provide one way of removing moisture from compressed air, after the compressor package and before distribution, they offer technical advantages on many installations. They are, however, likely to be net consumers of energy even though, for instance, heat recycling within the dryer or the use of recycled compression heat for dryer regeneration, can reduce the call on energy to a minimum. The use of dryers and, in general, the reduction of the dewpoint of compressed air should be closely related to the requirements of the plant and the equipment installed

Where waste heat of 80°C (176°F) or more is available, an alternative to air drying is the raising of the margin between likely air temperature and dewpoint by reheating the air and lagging the lines. This will increase the overall energy which can be drawn from the compressed air. A 40°C (72°F) increase in temperature saves 10 per cent of compressed air.

Hose, fittings and couplings

Leaks and restrictions should be avoided. This i matter of protection, maintenance, the avoidan of locations and procedures likely to result in damage, and of selecting the right diameters an types

4 *Efficient running of air-driven equipment*

Unless air-operated equipment such as pneum tools and directional control valves and cylinde are supplied with properly conditioned compressed air, wear of seals and other moving parts will occur, leading inevitably to loss in operating efficiency with possible leakage of compressed air and consequently energy wastag

Filters

It is equally important to ensure that a properly planned maintenance programme is implemented, not only for the air-operated equipment but also for the conditioning units' filters, pressure regulators and lubricators which service the tools and cylinders to keep the system operating at maximum efficiency, thus using minimum energy.

To remove pipe scale, water, and compressor oil, which can combine together to form highly abrasive compounds, the compressed air should be filtered close to the point at which it will be us to drive equipment.

Filters must be regularly serviced to clean or renew the elements which gradually become choked with dirt, thus causing excessive pressure drop and energy wastage.

The degree of filtration should be related to th application. The finer the pore size of the filter th more dirt it will collect and the more readily it wi become choked.

In the case of pneumatic instrumentation, measuring equipment and other applications requiring extremely clean air, it may be necessar to consider ultra-high efficiency filters to remov all traces of water and oil droplets. These specialised filters can easily cause excessive pressure drop if allowed to become choked with dirt, and it is advisable not only to protect items from excessive dirt contamination by using pre-filters, but also to continuously monitor the pressure drop across them (differential pressure gauge) so that appropriate action can be taken when this pressure drop exceeds the maker's recommended level.

5.1.3 Temperature Measurements

Temperature measurements also are important indicators of equipment function. Not only will compressor cooling media temperatures indicate difficulties with the cooling system, but elevated temperature rise also can result from failing cylinder lubrication, a defective unloader or worn valves. Similarly, above normal discharge air temperature can be caused by any of the same reasons and, also, by defective or improperly adjusted output controls.

Other system temperatures are used to monitor the performance of coolers and dryers. The most significant indicator of aftercooler fouling, or obstruction, is the approach temperature. This is the difference between the temperature of the air discharged from the aftercooler and the temperature of the coolant being supplied to the aftercooler.

All temperatures should be read when the system is new and operating properly so as to establish a baseline. These baseline temperatures should be compared to those indicated by equipment manufacturers as being representative design or specification temperatures. This will establish the basis for interpreting future operating temperatures as the system is used.

5.1.4 Leakage Testing

Of all the maintenance measurements needed, the detection and measurement of leakage probably requires more attention from a good maintenance program than any other item. There are many methods of finding leaks.

One of the favorites for all types of leakage in most places is simply the use of a can of soapy water and a paint brush. Such a technique should be applied immediately to all new installations and to all system modifications. Every pipe joint should be checked before the installers are released from their obligations. Although the soap bubble test still is by far the most reliable detector, even of relatively small leaks, its disadvantage is that seeking leaks throughout a large system requires personnel to cover meticulously all of the joints and connections which might be suspect. This could require a great deal of time.

A more modern approach, though perhaps not quite so sensitive as the use of soap bubbles, is the application of acoustic detectors. All air leaks make high frequency hissing sounds, the larger of which are clearly audible in most factories after the work has stopped and while the compressors still are running. An acoustic leak detector can be used to detect and locate these leaks. A number of manufacturers make good ones which are portable and with which an entire system can be scanned in a reasonable amount of time. They consist of small, directional microphones, amplifiers, audio filters and either or both of visual indicators and earphones. They are effective.

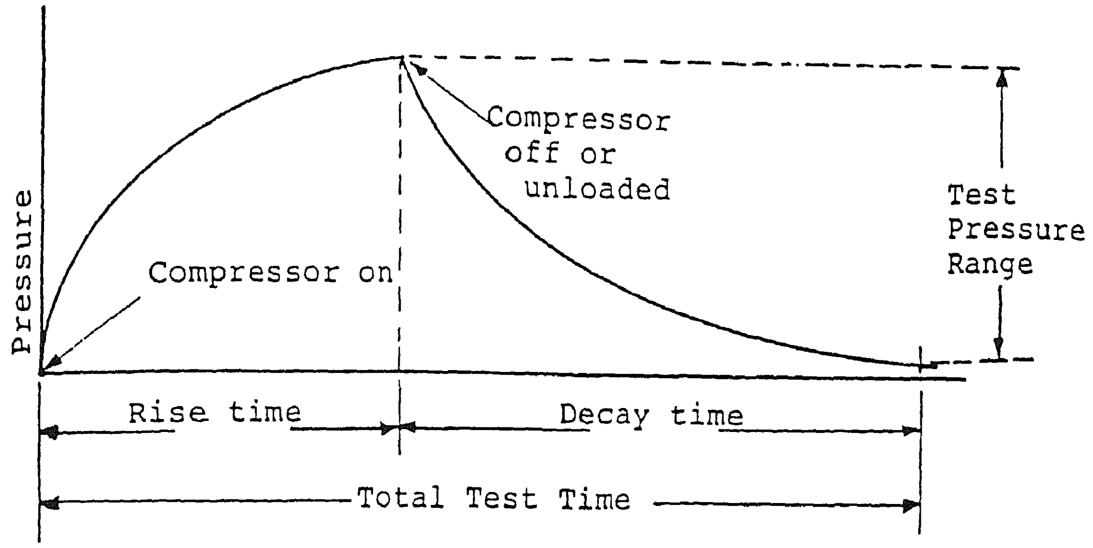
An integrated evaluation of total system leakage also is desirable in many factory installations. This can be achieved by operating a compressor on a Saturday or at night when no work is being performed. If the system has air flow measuring instruments, then the leakage can be measured in this way during weekends or off hours.

If there is no air flow instrumentation, and the compressor is known to be in good condition, then sometimes leakage can be determined by measuring the output of the compressor as a percent of its total capacity by observing its control systems in operation. For example, assume that at the average of the high and low controlled pressure, the capacity of the compressor is known to be X cubic feet per minute. Also, assume that it is controlled by alternately fully unloading and fully loading the compressor. If under these circumstances the loaded time is 30% of the total operating time during off hours when manufacturing operations are not taking place, then the leakage can be said to be close to 0.3X.

Once again, it is wise to perform such measurements on new systems to establish baseline information for a later comparison. Also, this type of test is best done just after performing a test or measurement of compressor operating characteristics to assure that it is operating at a known capacity.

Another method has been used which combines compressor capacity and system leakage measurements in the following way:

During off hours, a compressor is started and the time to bring the system to full pressure is carefully recorded. Then the compressor is turned off or unloaded, and the time for the system pressure to decay to a known value is recorded. This first is done when the system is new and all or almost all leaks have been eliminated. The times are recorded carefully. Future tests, then, will indicate condition change. If the system pressure decays more quickly than previously after shut-down of the compressor, then an increase in leakage is indicated. If, after the leaks are brought under control so that the decay time is the same, an increase in total test time or pressure rise time indicates a compressor in need of attention.



It is important to note here that, to control leakage, the responsible maintenance personnel must begin early and apply regular and continuous attention to the problem. By beginning when the equipment is new or newly refurbished, baseline information can be established and the first leaks corrected at the expense of the contractor or others who may have installed the system. Also, this will set a performance standard against which maintenance performance can be scheduled and evaluated.

5.1.5 Pressure Drop Measurements

Most compressed air equipment is, or should be, provided with input and output pressure gages. One important place where, frequently, this is not so is at work stations and places where tools may be attached, such as at the end of hoses. For this reason, every good maintenance department will have good, high-quality pressure gages for checking system pressure in remote areas. Once again, an early routine for regular pressure checks at the beginning of new system operations will provide baseline information helping to identify later difficulties with the distribution system. These difficulties could arise from overloading a portion of the system with too many drops and usages (factory operations change), new leaks, or line obstructions. Such on-the-spot evaluations can indicate undersized branch lines, drop lines, filter/lubricators, or hoses. Sometimes higher horsepower pneumatic devices are added to existing lines, rendering them inadequate. Good maintenance operations can sense and correct this problem before the tool users become frustrated.

The reading of actual pressure in a hose leading to a tool or portable pneumatic device is recommended. Most air motors suffer badly in operating function when air pressure is down, resulting in longer operating time and more total air used per operation. Several manufacturers offer a hypodermic needle pressure gage which can be inserted through the hose wall near the end connected to the tool or motor. The gage then is read while the tool is operating.

It is important to note that in many cases the maintenance personnel will be subtracting two pressure measurements in order to determine a pressure drop, such as the drop across a filter, because some installations of these pieces of equipment do not include the preferred pressure differential gages. Since most pressure gages are not of laboratory quality and may change in calibration with time, it is important that the pressures be read at least once and, perhaps, from time to time subsequently, when there is no air flow. The no-flow pressure readings all will be of the same pressure, and a recording of the differences will quantify gage errors which then can be compensated when pressure differences are being determined. Even so, determining pressure drop in this manner is inferior to the readings from pressure differential gages.

Pressure drop measurements are of great importance for filter condition monitoring. Systems equipped with filters also should have pressure differential gages, even if later retrofitted. Pressure differential alarms also are available and effective.

5.2 Financial Evaluation

The dominant consideration in deciding whether or not to take an action that may save energy is, of course, saving money. This dictates that all comparisons of alternate courses of action, or alternate pieces of equipment, should be reduced to a meaningful financial evaluation. In the final analysis will the cost of enlarging a header system justify its cost? Will compressor A be, in the long run, less costly to purchase and operate than compressor B? Which air dryer will offer the lowest lifetime cost? Is the extra cost of high efficiency electric motors economic? When should filters be changed for lowest total cost? There are a number of financial and accounting analytical methods which will produce criteria for sound value judgements of these types.

Annexure 8.1

MNES Soft Loan Scheme for Solar Thermal Systems

Solar Thermal Extension Programme
(Demonstration, Technology Utilization and Market Development)

Interest subsidy scheme

Under the Interest Subsidy Scheme, soft loans will be provided for solar thermal systems including solar water heaters through scheduled banks and IREDA Steps will be taken to expand the soft loan network to cover larger area of the country by extending the programme through more banks and other financial institutions and also by enlarging the area of operation of the existing banks. Branches of the banks covered under the scheme are authorized to offer loans to users in nearby towns and villages if there is no participating branch in these places (for example the branch of Punjab & Sind Bank in Vijayawada may offer loans to users in Guntur town which is about 35 km away). The rates of interest at which the loans can be extended to the users under the Interest Subsidy Scheme are given in Table-I. MNES will continue to provide the difference of interest rates between the normal lending rate of the bank and the rate of interest of the soft loan as interest subsidy. The normal lending rate will be subject to the guidelines issued by the Reserve Bank of India from time to time, wherever applicable.

Solar water heating systems of capacity up to a maximum of 2000 litres per day (lpd) of hot water will be eligible for soft loans through banks under the Interest Subsidy Scheme. The upper limit of loans to be extended by banks, IREDA or any other financial institution at reduced interest rates under the scheme will be 85%. Payments/grants on account of interest subsidy will be made by the Ministry for the period of the loans.

An additional amount of Rs.300 will also be made available by MNES to the banks as promotional incentive / business development charge for each loan disbursed irrespective of the size of the system. As soon as a loan is disbursed, an amount of Rs.300 can be debited by the bank to the MNES interest subsidy account. The funds so collected / accumulated can be used for the following purposes and in the following manner by the bank:

(i) (a) Commission to motivators / agents who bring in loan applications from potential buyers of solar products
    (b) Publicity expenses including advertisements, posters, brochures etc.
    (c) Other business development charges relating to solar energy products.

(ii) In order to keep the interest of the motivators/agents alive, it is advisable that the commission to the motivators / agents be paid at the branch level itself and a debit advice will be sent to the nodal branch.

Table I Rates of Interest under the Interest Subsidy Scheme

Technology	*Implementing Organization*	*Category of end-user*	*Rate of Interest*
Solar water heating system (up to 2000 litres capacity)	Banks / HUDCO etc.	Individual, institution, association, small business establishment	5%* (to end user)
Solar water heating system (up to 2000 litres capacity)	IREDA (through financial intermediaries). IREDA provides loans to financial intermediaries @ 2.5% rate of interest	Individual, institution, association, small business establishment	5%* (to end user)
Solar water heating system (any capacity), Solar air heating system, solar desalination system, solar swimming pool	IREDA (direct or through financial intermediaries)**	Institutions, trusts, charitable organizations etc. (non-profit organizations)	5% *
Solar water heating system (any capacity), solar air heating system, solar desalination system, solar swimming pool	IREDA (direct or through financial intermediaries)**	Industry, hotels and other commercial organizations (profit making)	8.3%

* End-users (other than individuals) will have to give an undertaking that no depreciation allowance will be claimed under income tax rules.

** The financial intermediaries may charge a spread up to 4% over the rate charged from them by IREDA.

- Release of funds - norms

  Solar thermal extension programme

  (interest subsidy through banks / IREDA)

  The release of funds will be governed by the MoUs with these organizations.

Terms of Loans under the Bank Scheme

<table>
<tr><td>Capacity</td><td colspan="2">Up to 2000 litres of hot water at 60-80 C per day</td></tr>
<tr><td>Loan amount</td><td colspan="2">85% of the ex-factory or ex-showroom cost of the system</td></tr>
<tr><td>Interest rate for soft loan</td><td colspan="2">5% per annum</td></tr>
<tr><td>Loan repayment period</td><td colspan="2">5 years</td></tr>
<tr><td>Repayment starts at</td><td colspan="2">3 months after the release of funds to the consumers</td></tr>
<tr><td>Penalty for defaulted loans</td><td colspan="2">For defaulted loans banks may charge penal interest @ 2% over and above the stipulated interest rate.</td></tr>
<tr><td>Eligibility for loan</td><td colspan="2">Any individual, institution, association, business establishment etc.</td></tr>
<tr><td>Eligible suppliers</td><td colspan="2">Suppliers of solar water heaters with BIS (Bureau of Indian Standards) approved solar collectors</td></tr>
<tr><td colspan="3">Upper limit of cost of solar water heating systems to be financed by banks (for guidance only)</td></tr>
<tr><td>System with collector area</td><td>Approximate capacity</td><td>Cost</td></tr>
<tr><td>1 no. collector system (2 sq.mt. approx)</td><td>100 litres</td><td>Rs.18,000</td></tr>
<tr><td>2 nos. collector system (4 sq.mt. approx)</td><td>200 litres</td><td>Rs.35,000</td></tr>
<tr><td>3 nos. collector system (6 sq.mt. approx)</td><td>300 litres</td><td>Rs.50,000</td></tr>
<tr><td>4 nos. collector system (8 sq.mt. approx)</td><td>400 litres</td><td>Rs.65,000</td></tr>
<tr><td>5 nos. collector system (10 sq.mt. approx)</td><td>500 litres</td><td>Rs.80,000</td></tr>
<tr><td>6 nos. collector system and onwards upto 20 nos. collector system</td><td>600 litres</td><td>Rs.14,500 for each collector</td></tr>
</table>

i.e. for 10 nos. collector system (20 sq.mt. approx)	1000 litres	Rs.1,45,000
For 15 nos. collector system (30 sq.mt. approx)	1500 litres	Rs 2,17,500
For 20 nos. collector system (40 sq.mt. approx)	2000 litres	Rs.2,90,000
Maintenance guarantee	Suppliers will be responsible for maintenance of the systems for 5 years and it will form part of unit cost to be financed by the banks as per above guidelines.	
The cost indicated above includes the cost of collector, insulated hot water storage tank, system pipings, instrumentation, controls etc. The cost also includes maintenance responsibility of the systems by the manufacturers for five years. The bank will provide 85% of the cost of the system as soft loan.		

Eligible Suppliers

Buyers of solar water heaters of capacity up to a maximum of 2000 litres per day (lpd) of hot water are eligible for soft loans through designated banks under the Interest Subsidy Scheme of the Ministry. The projects being financed under this scheme must utilize BIS (Bureau of Indian Standards) approved solar collectors (IS 12933:1992). Systems supplied by the following are eligible for financing:

- Manufacturers of BIS certified collectors.
- Business associates / authorized dealers of such manufacturers, on production of a letter from the manufacturers.

The cost of a solar water heater must also include maintenance responsibility of the system by the manufacturers for five years. The bank will provide 85% of the cost of the system as soft loan at 5% annual rate of interest payable within 5 years. The users of the solar water heaters (other than individuals) are also required to give an undertaking that no accelerated depreciation allowance will be claimed under income tax rules.

List of manufacturers of BIS approved solar flat plate collectors

Sl.No.	*Manufacturer*	*Licence No.*
1.	BHARAT HEAVY ELECTRICALS LTD. 16th Floor, Hindustan Times House, 18-20, Kasturba Gandhi Marg, New Delhi – 110 001. Tel: (011) 3323199, 3327547 Fax: (011) 3721680	9036369
2.	DHEEMANTH INDUSTRIES, No.35, Kamakshipalya, (Behind Check Post),Vijayanagar, Bangalore – 560 079 Tel: (080) 3359377	6085670
3.	EMVEE SOLAR SYSTEMS, No.253, 5th Main road, 10th Cross, Vasanthappa Block, Bangalore – 560 032 Tel: (080) 3337033, 3331950 Fax: (080) 3334804 e-mail: emmvee@vsnl.com	6085569
4.	ENOLAR SYSTEMS, No. 1567, 7th Cross, 2nd Main, Govinda Raja Nagar, Bangalore – 560 079 (Karnataka) Telefax: (080) 3355333, 3385500	6093063
5.	SURYODAYA HI-TECH ENGINEERING (P) LTD., 1-10-68/4, Chikoti Gardens, Begumpet, Hyderabad – 500 016. Tel: (040) 7765831, Fax: (040) 7767813	6097576
6.	SURYA JYOTI DEVICES (INDIA) PVT. LTD., Village Challon, PO Kurali, District Ropar, Punjab. Tel: (01888) 32039, 32340	9068786
7.	TATA BP SOLAR INDIA LTD., Plot No.78, Electronics City, Hosur Road, Bangalore – 561229 Tel: (080) 8520082/3 & 8520973/4 Fax: (080) 8520972/116 e-mail: tatabp@solar.ind.bp.com,	6102947

Sl.No.	*Manufacturer*	*Licence No.*
8.	SABHA SOLAR ENERGY, Flat No.1/D, No.5, 9th Main Road, (Behind Rajmahal Mini Market), Rajmahal Vilas Extn., Sadashivnagar, Bangalore – 560080 Tel: (080) 3340245, 3342980 Fax: (080) 33456221	6117657
9.	SUNTRAP DEVICES, B-49, N.G.O. "B" Colony, Tirunelveli – 627007 (Tamilnadu) Tel: 0462-553693 e-mail: suntrap@md4.vsnl.net.in	6109759
10.	SIGMA STEEL & ENGINEERS (P) LTD., 225/11, Bagmari Road, Calcutta – 700054 Tel: (033) 3515942 e-mail: ssepl@cal.vsnl.net.in	5073961
11.	MACHINOCRAFT, 15/4A, Vasudeo Estate, Opp.Shankar Maharaj Temple, Pune-Satara Road, Pune – 411043 Tel: (0212) 571457, 573923(New Nos.) Fax: (0212) 574623 e-mail: machino@pn2.vsnl.net.in	7130755
12.	SURYAKIRAN PVT. LTD., Development Area, Binanipuram PO, Edayar, Kochi – 683 502 Tel: 0484 559184	6115552
13.	ANKUR SCIENTIFIC ENERGY TECHNOLOGY PVT. LTD., 'ANKUR' , Near Old Sama Jakat Naka, Baroda – 390008 Tel: (0265) 793098/794021 Fax: (0265) 794042 e-mail: ascent@wilnetonline.net.in	7128566
14.	PEENYA ALLOYS, No.248 III Phase III Cross, Peenya Industrial Area, 18th Main, Bangalore – 560058 Tel: (080) 8394259 Fax: (080) 8396536	6130851

Sl.No.	*Manufacturer*	*Licence No.*
15.	ENOLAR SYSTEMS MARKETING, 916 Third Main Road, Vijaya Nagar, Bangalore – 560040 Tel: (080) 3388792 e-mail: enolar@hotmail.com	6125858
16.	SWAMY SOLAR SYSTEMS, "Sapthagiri Nivas", 117/10, Main Channel Road, Lingahinapalya, Ulsoor, Bangalore – 560008 Tel: (080) 5545131, 5252731 Fax: (080) 5561250	6140551
17.	NUETECH SYSTEMS, Post Box No.9167, B.M. Shankarappa Industrial Estate, Sunkadakatte, Vishwaneedam Post, Magadi Main Road, Bangalore – 91 Tel: (080) 3483766, 3481905 Pager: 9628804534	6134657
18.	SUDARSHAN SAUR SHAKTI PVT. LTD., 35, Bhagya Nagar, Aurangabad – 431001 Tel: (0240) 333491, 331842 Fax:(0240) 356197 e-mail:sudarsh@bom4.vsnl.net.in	7154264
19.	BIPIN ENGINEERS PVT. LTD., Survey No.143, Wadgaon Dhairy, Sinhgad Road, Pune – 411041. Telefax No.(212) 802064, 802084 e-mail:bipsunindia@hotmail.com, hemant@giasp01.vsnl.net.in	7161867
20.	KOTAK URJA PVT. LTD., 226, Ist Floor, Opp.Sai Baba Temple, 14th Cross, Sampege Road, Malleshwaram, Bangalore – 560 003. Tel: (080) 3560456 / 57 Fax: (080) 3562233 e-mail: kotakurja@vsnl.com, urja@mcdecom.net	6144761

Sl.No.	Manufacturer	Licence No.
21.	KAUSHAL SOLAR EQUIPMENTS (P) LTD., 767/7, Neel-Kusum, Near P.Y.C. Gymkhana, Pune-411004 Tel (020) 5676379 / 5670472 Fax(020) 5677789 e-mail: kaushalsolar@vsnl.com	7167576
22.	JAIN IRRIGATION SYSTEMS LTD., Solar Division, Jain Park, Mohadi Road, Jalgaon 425001 Tel (0257) 220033, 220055 Fax (0257) 221133, 221155 e-mail: agricul@bom6.vsnl.net.in	7164368
23.	M/S. SUNRISE SOLAR PVT. LTD. P.B.No. 2130, 1190/8, 13th Main Road, Prakash nagar, Bangalore-560021. Tel (080) 3328533 e-mail: solar@bgl.vsnl.net.in	6148365
24.	SURYA SHAKTI, 739, Industrial Area, Phase-II, Chandigarh Tel (0172) 653299, 773214 Fax (0172) 771576	9168689
25.	TECHNOMAX SOLAR DEVICES, No.4 A, Venkateshwara School Street, R.M.V. II Stage, Nagashetty Hally, Bangalore – 560094 Tel (080) 3418723	6148163
26.	PRABHU ENERGY SYSTEMS, 2nd Floor, Hameed Complex, Kuloor Ferry Road, Alake, Mangalore – 575003 Tel (0824) 491967 Fax (0824) 458315 e-mail: prbengsy@sancharnet.in	6148567
27.	SOLCHROME SYSTEMS INDIA LIMITED, 161, Sukhdev Vihar, New Delhi – 110 025 Tel (011) 6838365, 6848228 Fax (011) 6835160 ssil@solchrome.com	9180982

Sl.No.	*Manufacturer*	*Licence No.*
28.	M. LAXMAN & CO., 15-A/2, PWD Colony, Near Varunraj Hotel, Erandwane, Karve Road, Pune – 411004.	7178480
29.	SAVEMAX SOLAR SYSTEMS PVT. LTD., Jayaprabha, Jadhavnagar, Vadgaon Bk., Pune – 41. Tel (020) 4358613, 4358781 Fax (020) 4358613 e-mail: savemax@vsnl.com	7178682
30.	PITTIE SOLAR PVT. LTD., 37/1B, Vadgaon Sheri, Pune – 411014 Tel (020) 7033417, 4003091 e-mail: pittie@vsnl.com	7180669
31.	M/S. SURYA SHAKTHI, # 2, Ist Floor, Sree Bharathi, V.H.B.C.S. Layout, Basaveshwaranagar Ist Stage, Magadi Main Road, Bangalore – 560079 Tel: (080) 3486138, 3487342, 9845053216	6153358
32.	M/S. JAY INDUSTRIES, D-64, M.I.D.C., Miraj – 416410 (Maharashtra) Tel (0233) 344658 Fax (0233) 344464 e-mail: jaysolar@yahoo.com, jaysolar@usa.net	7179381
33.	M/S. STANDARDS ENGINEERING CO., 131/7B, 'Chandan' Hadapsar Industrial Estate, Pune – 411 013. Tel (0212) 670237 Fax (0212) 670414 pungaliya@mantramail.com	7186883
34.	M/S. NRG TECHNOLOGIES, 989/6, G.I.D.C., Makarpura, Vadodara – 390 010 (Gujarat) Tel (0265) 642094 nrgtechnologists@yahoo.com	719498
35.	M/S. SOLAR PRODUCT CO., II / 61, Mukund Nagar, Pune – 411 037 Tel (0212) 464182 Fax (0212) 369815	7201146

Sl.No.	*Manufacturer*	*Licence No.*
36.	M/S. SOLAR ENERGY SERVICES, Plot No.303, Savli GIDC Estate, Savli , Near Village Manjusar, Savli Road, Dist. Vadodara – 391775 Tel (0265) 337674 , 351703	7220756
37.	M/S. DIVYA INDUSTRIES, 814, Chowdeshwari Nagar, Laggeri Main Road, Laggeri Peenya, Post, Bangalore- 560058 Tel (080) 8398471	6165870
38.	Kraftwork Solar Private Limited, Door No.VI/99-A, Major Industrial Estate, PO Kalamassery D.P., Kochi – 683 109 (Kerala). Tel(484) 542337 Fax(484)370073 kraftworksolar@usanet	6185775
39.	INTER SOLAR SYSTEMS (P) LTD., Plot No.39, Industrial Area, Phase-II, Chandigarh – 160 002. Tel (0172) 655349, 579002 Fax (0172) 652319 e-mail: intersolar@glide.net.in	9217777
40.	M/S. KHAMBETE AND KHAMBETE, 65-66, Audyogik Vasahat, Ajintha Road, Jalgaon – 425 003. Tel (0257) 210650, 210206 Fax (0257) 210948 khambete@bom6.vsnl.net.in	7258377
41.	M/S. SOLAR CATCHER, 9/10, Bendrenagar, Subramanyapur Main Road, Bangalore - 560 070 Tel (080) 6663129, 6660161	6211548
42.	M/S. STANDARD PRODUCTS MFG. CO., 2/14, Marol Coop. Indl. Estate, M. Vassanji Road, Sakinaka, Andheri (E), Mumbai – 400 059. Tel.(022) 850 0970 Fax(022) 850 6703	7257375

Sl.No.	*Manufacturer*	*Licence No.*
43.	M/S.VIJAYA INDUSTRIES, 166/2, Katapady – 574 105 Udupi Dist, Karnataka Tel (08252) 557127, 557327 Fax (08252) 557700 e-mail vijaya-vip@zetainfotech.com	6223959
44.	M/S. MASTER ENGINEERS, Sl.No.139, Warje Malwadi, Dudhane Estate, Pune – 411 052 Tel: 020-5290499 Mobile: 9822062487	7247978
45.	M/S SHRINGAR ENGINEERING & ENERGY SYSTEMS PVT. LTD. C-74, III Stage, Peenya Industrial Area, Bangalore – 560 058. Tel; (080) 836 2304 suryakanthi@vsnl.net.in	6215556
46.	M/S. RASHMI INDUSTRIES, No.60 & 61, Begur Road, Hongasandra Village, Bangalore – 560 068 Tel.080-5734115, 5734114 Fax 080-5732309 hpngroup@vsnl.net.	6235562
47.	M/S. YESHOMA INDUSTRIES, No.59 (New No.8), 3rd Cross, Ittamadu Village Extn., Banashankari 3rd Stage, Bangalore – 560 085 Tel. (080) 2235029, 624991	6240555
48.	M/S. NAMSI SOLAR PRIVATE LIMITED, No.240, 2nd Floor, 32nd Cross, 7th Block, Jayanagar, Bangalore – 560 082. Tel: (080) 6647308 Fax: (080) 6644429 info@namsisolar.com	6282268
49.	M/S ERENA TECHNOLOGIES (INDIA), No.52, Doddanna Industrial Estate, Near Peenya 2nd Stage, Bangalore – 560 091(Karnataka) Tel: 080 – 8364014	6267878

Sl.No.	*Manufacturer*	*Licence No.*
50.	M/s. STEELHACKS INDUSTRIES, 9A/1, GIDC, Vithal Udyognagar – 388 121 (Gujarat) Tel: 0091-2692-36156, 35558 Fax: 0091-2692-36534 unisol@icenet.net	7335268
51.	M/S DECCAN ELECTRO WORKS PANEL DIVISION, G-76, MIDC Gokul Shirgaon, Taluka Karveer, Dist Kolhapur - 416 234 Tel: 0231 - 672984	7337272
52.	M/S SOLKER INDUSTRIES LTD., No.436, Sidco Industrial Estate, Behind Telephone Exchange, Ambattur, Chennai – 600 098 Tel: 44-8274142, 8271819 Fax: 44-8273435 e-mail: solker20@hotmail.com, sales@solker.com	6287682
53.	M/S JYOTHI SOLAR EQUIPMENTS PVT. LTD., No.1, Tatanagar, Kodigehalli, Nagashetty Halli Main Road, Sahakara Nagar Post, Bangalore – 560 092 Tel: 3417020, 3511579	6299689
54.	M/S. SUNCARE SOLAR SYSTEMS PVT. LTD. 3 & 4, Buddanna Indl.Estate, Vidyapeetha Road, Kengeri, Bangalore – 560 060 Tel: 080-8483044	6300042
55.	M/S. MARUT ENERGY EQUIPMENTS PVT. LTD., D-1/18, MIDC, Ambad, Nashik – 422 010 Tel: (0253) 804910 Fax: (0253) 384061 e-mail: marketing@solarecindia.com	7359787
56.	M/S. HONEY HILLS SYNERGY SYSTEMS, No.365, IV Phase, Peenya Industrial Area, Bangalore – 560 058 Telefax : 8361282, 8361469	6309060

Sl.No.	*Manufacturer*	*Licence No.*
57.	M/S. GANGA INDUSTRIES, No.4020/3562, B.M. Shankarappa Industrial Estate, Sunkada Katte, Magadi Main Road, Vishwaneedam Post, Bangalore – 560 091. Tel: 080-3285031	6309262
58.	M/S. AEGIS ASSOCIATES, 99/20, 20A, Doddanna Indl. Estate, Near Peenya IInd Stage, Bangalore – 560 091 Tel: 080-8360847 Fax: 080-8361080 e-mail: aegis@bplnet.com	6313556

Participating Banks and Area of Operation

Name of the Bank	*Area of operation*
Canara Bank	Bangalore, Mangalore, Mysore, Gulbarga, Shimoga, Sagar, Tumkur, Mandya, T. Narasipura, Nanjangud, Bijapur, Bidar, Raichur, Koppal, Davangere, Hassan, Chickmagalur, Madikeri, Hubli, Belgaum, Gadag, Ranebennur, Udupi, Kundapur, Puttur, Bhadravathi, Thirthahalli, Hosanagar, Kumta, Karwar, Maski, Gangavathi, Nagamangala, Sindhanoor, Hospet, Chitradurga, Chellakere, Hiriyur (Karnataka), Panaji (Goa), Chennai, Coimbatore, Salem, Erode, Pollachi, Tirupur (Tamilnadu) Pune, Kolapur, Satara, Solapur, Srigonda (Maharashtra), Agra, Aligarh, Kanpur, Lucknow (Uttar Pradesh), Trivandrum, Ernakulum, Calicut, Trichur (Kerala), New Delhi,
Union Bank of India	All branches in the States of Maharashtra & Uttar Pradesh and the following cities : Ahmedabad, Surat, Baroda, Rajkot, Bhavnagar, Bhopal, Indore, Jabalpur, Gwalior, Jaipur, Udaipur, Jodhpur, Mount Abu, Delhi, Chandigarh, Hyderabad, Calcutta, Bangalore, Bhubaneshwar, Chennai, Guwahati, Thiruvananthapuram, Shimla, Patna, Trichy, Ranipet, Coimbatore, Madurai, Ranchi, Jamshedpur, Dhanbad, Muzaffarpur, Durgapur, Siliguri, Agartala, Shillong, Vishakhapatnam, Raipur, Bilaspur, Kota, Mysore, Cochin, Pondicherry, Panaji and Vellore.
Andhra Bank	All branches at Hyderabad, Secunderabad, Vijayawada, Visakhapatnam, Rajahmundry, Kakinada, Vizianagaram, Machilipatnam, Guntur, Ongole, Nellore, Tirupati, Anantapur, Kurnool, Mahabubnagar, Nizamabad, Adilabad, Warangal, Karimnagar, Chennai, Coimbatore, Madurai, Thiruvananthapuram, Bangalore, Mumbai, Pune, Ahmedabad, Baroda, Delhi, Jaipur, Chandigarh, Lucknow, Kolkata, Bhubaneswar and Bhopal.
Bank of Maharashtra	**All branches in the country.**

Name of the Bank	*Area of operation*
Punjab & Sind Bank	All branches in the **States of Punjab, Haryana and UT of Chandigarh** and the following cities : Shimla, Paonta Sahib, Meerut, Dehradun, Bareilly, Lucknow, Kanpur, Agra, Saharanpur, Hardwar, Aligarh, Gaziabad. Allahabad, Pilibhit, Shahjehanpur, Muzaffarnagar, Rampur, Muradabad, Nainital, Rudrapur, Ajmer, Jaipur, Jodhpur, Kota, Sri Ganganagar, Udaipur, Bikaner, Bhopal, Indore, Bhilai, Gwalior, Jabalpur, Ujjain, Mumbai, Aurangabad, Nanded, Nagpur, Panaji, Ahmedabad, Baroda, Surat, Jamnagar, Bidar, Bangalore, Mysore, Mangalore, Ernakulum, Thiruvananthapuram, Quilon, Hyderabad, Secunderabad, Vijayawada, Visakhapatnam, Chennai, Coimbatore, Kolkata, Siliguri, Patna, Dhanbad, Gaya, Bhagalpur, Jamshedpur, Ranchi, Bhubaneshwar and Cuttack
Syndicate Bank	All branches in the country
Punjab National Bank	All branches in the country